International Association of Oil & Gas Producers

SPECIFICATION

IOGP S-704J

November 2024

Version 2.0

Supplementary Specification to IEC 60034-1 for High-voltage Three-phase Cage Induction Motors

NOTE This version (S-704J) of the specification document provides the justification statements for each technical requirement, but is otherwise identical in content to S-704.

JIP33 JOINT INDUSTRY PROGRAMME

Revision history

VERSION	DATE	PURPOSE
2.0	November 2024	Second Edition
1.0	January 2021	First Edition

Acknowledgements

This IOGP Specification was prepared by a Joint Industry Programme 33 Standardization of Equipment Specifications for Procurement organized by IOGP with support by the World Economic Forum (WEF).

Foreword

This specification was prepared under Joint Industry Programme 33 (JIP33) "Standardization of Equipment Specifications for Procurement" organized by the International Oil & Gas Producers Association (IOGP) with the support from the World Economic Forum (WEF). Companies from the IOGP membership participated in developing this specification to leverage and improve industry level standardization globally in the oil and gas sector. The work has developed a minimized set of supplementary requirements for procurement, with life cycle cost in mind, resulting in a common and jointly agreed specification, building on recognized industry and international standards.

Recent trends in oil and gas projects have demonstrated substantial budget and schedule overruns. The Oil and Gas Community within the World Economic Forum (WEF) has implemented a Capital Project Complexity (CPC) initiative which seeks to drive a structural reduction in upstream project costs with a focus on industry-wide, non-competitive collaboration and standardization. The CPC vision is to standardize specifications for global procurement for equipment and packages. JIP33 provides the oil and gas sector with the opportunity to move from internally to externally focused standardization initiatives and provide step change benefits in the sector's capital projects performance.

This specification has been developed in consultation with a broad user and supplier base to realize benefits from standardization and achieve significant project and schedule cost reductions.

The JIP33 work groups performed their activities in accordance with IOGP's Competition Law Guidelines (November 2020).

This second edition cancels and replaces the first edition published in January 2021. Due to technical writing requirements leading to extensive changes, this second edition should be treated as a new document.

Table of contents

List of tables

Introduction

The purpose of the IOGP S-704 specification documents is to define a minimum common set of requirements for the procurement of high-voltage three-phase cage induction motors in accordance with IEC 60034-1, Edition 14.0, 2022, Rotating electrical machines – Part 1: Rating and performance, for application in the petroleum and natural gas industries.

The IOGP S-704 specification documents follow a common structure (as shown below) comprising a specification, also known as a technical requirements specification (TRS), a procurement data sheet (PDS), an information requirements specification (IRS) and a quality requirements specification (QRS). These four specification documents, together with the purchase order, define the overall technical specification for procurement.

JIP33 Specification for Procurement Documents
Supplementary Technical Requirements Specification (TRS)

This specification is to be applied in conjunction with the supporting PDS, IRS and QRS as follows.

IOGP S-704: Supplementary Specification to IEC 60034-1 for High-voltage Three-phase Cage Induction Motors

This specification defines technical requirements for the supply of the equipment and is written as an overlay to IEC 60034-1, following the IEC 60034-1 clause structure. Clauses from IEC 60034-1 not amended by this specification apply as written. Modifications to IEC 60034-1 defined in this specification are introduced by a description that includes the type of modification (i.e. *Add*, *Replace* or *Delete*) and the position of the modification within the clause.

NOTE Lists, notes, tables, figures, equations, examples and warnings are not counted as paragraphs.

IOGP S-704D: Procurement Data Sheet for High-voltage Three-phase Cage Induction Motors (IEC)

The PDS defines application-specific requirements. The PDS is applied during the procurement cycle only and does not replace the equipment data sheet. The PDS may also include fields for supplier-provided information required as part of the purchaser's technical evaluation. Additional purchaser-supplied documents may also be incorporated or referenced in the PDS to define scope and technical requirements for enquiry and purchase of the equipment.

IOGP S-704L: Information Requirements for High-voltage Three-phase Cage Induction Motors (IEC)

The IRS defines information requirements for the scope of supply. The IRS includes information content, format, timing and purpose to be provided by the supplier, and may also define specific conditions that invoke the information requirements.

IOGP S-704Q: Quality Requirements for High-voltage Three-phase Cage Induction Motors (IEC)

The QRS defines quality management system requirements and the proposed extent of purchaser conformity assessment activities for the scope of supply. Purchaser conformity assessment activities are defined through the selection of one of four generic conformity assessment system (CAS) levels on the basis of evaluation of the associated service and supply chain risks. The applicable CAS level is specified by the purchaser in the PDS or in the purchase order.

The specification documents follow the editorial format of IEC 60034-1 and, where appropriate, the drafting principles and rules of ISO/IEC Directives Part 2.

The PDS and IRS are published as editable documents for the purchaser to specify application-specific requirements. The TRS and QRS are fixed documents.

The order of precedence of documents applicable to the supply of the equipment, with the highest authority listed first, shall be as follows:

a) regulatory requirements;

b) contract documentation (e.g. purchase order);

c) purchaser-defined requirements (e.g. PDS, IRS and QRS);

d) this specification;

e) IEC 60034-1.

1 Scope

Add new subclause

1.1 Motors included in scope

The scope of this specification includes the following types of electric motors:

– with a form-wound stator coil AC squirrel cage induction type;

– with a rated power 100 kW or greater;

– with a rated voltage above 1 kV AC;

– with air or water cooling;

– with rolling element bearings, sleeve bearings or tilted pad thrust bearings;

– suitable for hazardous and non-hazardous area environments;

– for single-speed, converter duty or converter capable applications.

In this specification, the requirements for converter duty applications are also applicable to converter capable applications.

Justification

This subclause indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined by the work group in the statement of intent. The value of 100 kW is taken from Table 1.

Add new subclause

1.2 Motors excluded from scope

The scope of this specification excludes the following types of electric motors:

– with a wire-wound stator coil type;

– submersible, subsea, canned or hermetically sealed;

– DC;

– synchronous.

Justification

This subclause indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined by the work group in the statement of intent.

Add new subclause

1.3 Extended use of this specification

This specification may be used as a basis for the purchase of electric motors that are outside the immediate scope of this specification. The extended use of this specification based on similar construction and cooling methods may include the following:

– induction generators;

- form-wound motors with a rated voltage below 1 kV;
- multi-speed motors;
- motors with rated speed above 3600 rpm;
- reverse-speed motors;
- motors with magnetic bearings.

Those parameters that are outside the scope of this specification are subject to agreement between the purchaser and the manufacturer.

Justification

This subclause indicates the change in scope in comparison with IEC 60034-1. It aligns with the scope of this specification as defined by the work group in the statement of intent.

2 Normative references

Add to first paragraph

The following documents are referred to in this specification, the PDS (IOGP S-704D) or the IRS (IOGP S-704L) in such a way that some or all of their content constitutes requirements of these specification documents.

Add to clause

ANSI/NEMA MG 1, *Motors and Generators*

API Standard 541:2014 (Reaffirmed 2021), *Form-wound Squirrel Cage Induction Motors—375 kW (500 Horsepower) and Larger*

API Standard 670, *Machinery Protection Systems*

IEC 60034-2-1:2024, *Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60034-2-3, *Rotating electrical machines - Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC motors*

IEC 60034-7, Rotating electrical machines – Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code)

IEC 60034-14:2018, *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity*

IEC TS 60034-25:2022, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

IEC 60034-27-1, *Rotating electrical machines – Part 27-1: Off-line partial discharge measurements on the winding insulation*

IEC 60034-27-2, *Rotating electrical machines – Part 27-2: On-line partial discharge measurements on the stator winding insulation*

IEC 60034-27-3, *Rotating electrical machines – Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines*

IEC 60072-2, *Dimensions and output series for rotating electrical machines – Part 2: Frame numbers 355 to 1000 and flange numbers 1180 to 2360*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60423:2007, *Conduit systems for cable management – Outside diameters of conduits for electrical installations and threads for conduits and fittings*

IEC 60751, *Industrial platinum resistance thermometers and platinum temperature sensors*

IEC 61000-2-4:2002, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC 61800-2:2021, *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for adjustable speed AC power drive systems*

IEEE 112:2017, *IEEE Standard Test Procedure for Polyphase Induction Motors and Generators*

IEEE 519:2014, *IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*

IEEE 522, *IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines*

IEEE 1799, *IEEE Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings*

ISO 15, *Rolling bearings — Radial bearings — Boundary dimensions, general plan*

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 492, *Rolling bearings — Radial bearings — Geometrical product specifications (GPS) and tolerance values*

ISO 1680, *Acoustics — Test code for the measurement of airborne noise emitted by rotating electrical machines*

ISO 5753-1:2009, *Rolling bearings — Internal clearance — Part 1: Radial internal clearance for radial bearings*

ISO 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-2, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 2: Classification of environments*

ISO 21940-11 including AMD1:2022, *Mechanical vibration — Rotor balancing — Part 11: Procedures and tolerances for rotors with rigid behaviour*

ISO 21940-12, *Mechanical vibration — Rotor balancing — Part 12: Procedures and tolerances for rotors with flexible behaviour*

ISO 21940-32, *Mechanical vibration — Rotor balancing — Part 32: Shaft and fitment key convention*

Delete from clause

IEC TS 60034-25:2014, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

Replace Clause 3 title with

3 Terms, definitions and abbreviated terms

Add new subclause 3.0 to start of clause

3.0 Abbreviated terms

CAS conformity assessment system

Ex explosive atmosphere

FAT * factory acceptance test

FEA * finite element analysis

GRP * glass reinforced plastic

IRS information requirements specification

MRB * manufacturer's record book

PDS procurement data sheet

QRS quality requirements specification

RTD resistance temperature device

TRS technical requirements specification

VPI vacuum pressure impregnated

* Cited in IOGP S-704J only.

Add new term 3.38

3.38
critical speed
shaft rotational speed at which a machine component (e.g. shaft, rotor) is in a state of resonance

Add new term 3.39

3.39
maximum continuous operating speed
highest rotational speed at which the motor, as-built and tested, is defined for continuous operation, expressed as revolutions per minute [min^{-1}]

Add new term 3.40

3.40
minimum continuous operating speed
lowest rotational speed at which the motor, as-built and tested, is defined for continuous operation, expressed as revolutions per minute [min-[1]]

4 Duty

4.2 Duty types

4.2.9 Duty type S9 – Duty with non-periodic load and speed variations

In second sentence of fourth paragraph, replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

Justification

Edition 4.0 (2022) supersedes Edition 3.0 (2014).

4.2.10 Duty type S10 – Duty with discrete constant loads and speeds

In second sentence of last paragraph, replace "IEC TS 60034-25:2014" with

IEC TS 60034-25:2022

Justification

Edition 4.0 (2022) supersedes Edition 3.0 (2014).

5 Rating

5.5 Rated output

5.5.2 AC generators

In first paragraph, replace "volt-amperes (VA)" with

kilovolt-amperes (kVA)

Justification

The high-voltage generator power rating is expressed in kVA, which is consistent with supplier catalogues, international standards and industry practices.

5.5.3 Motors

Replace "watts (W)" with

kilowatts (kW)

Justification

The high-voltage motor power rating is expressed in kW, which is consistent with supplier catalogues, international standards and industry practices.

5.6 Rated voltage

5.6.2 AC generators

Replace "7.3" with

7.4

Justification

This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.

5.8 Machines with more than one rating

In second sentence of last paragraph, replace "7.3" with

7.4

Justification

This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.

Add new subclause

5.9 Efficiency

For 2-pole, 4-pole and 6-pole motors, compliance with Table 23 shall be confirmed at the rated voltage and frequency in accordance with IEC 60034-2-1:2024, Table 2.

Justification

Defining minimum efficiency requirements demonstrates JIP33's intent to reduce carbon emissions and capitalize on new technologies to ensure that environmental considerations have been addressed. IEC 60034-30-1 defines IE3 (international efficiency standard) as premium efficiency for low-voltage motors, however high-voltage does not have an equivalent definition for efficiency. New Table 23 has been developed from existing operator values. Testing requirements for single-speed machines are as per IEC 60034-2-1. For converter duty motors, testing is performed with a sinusoidal sine wave supply as per single-speed motors to provide a benchmark of efficiency. It is acknowledged that the converter supply has an adverse effect on efficiency, however this requirement ensures that testing can be standardized.

NOTE Efficiency of motor with 8-pole and above is declared by the manufacturer.

Add new Table 23

Table 23 – Minimum efficiency of high-voltage motor

Power rating kW	**2-pole motor efficiency value** %	**4-pole motor efficiency value** %	**6-pole motor efficiency value** %
185	94,2	94,6	93,5 [a]
200	94,5	94,7	93,6 [b]
220	94,7	95,1	93,8 [b]
250	95,1	95,2	94,0 [b]
280	95,3	95,4	94,2 [b]
300	95,4	95,5	94,3 [a]
315	95,5	95,5	94,5 [b]
335	95,6	95,6	94,6 [a]
355	95,7	95,7	94,7 [b]
375	95,8	95,8	94,8 [a]
400 - 500	96,0	96,0	95,3 [a]
530 - 570	96,2	96,2	95,5 [a]
800 - 950	96,4	96,4	96,1 [a]
≥ 1 000	96,5	96,5	96,4 [a]

[a] These values are interpolated values that are not listed in IEC 60034-30-3:2024, Table 4.

[b] These values are adopted from IEC 60034-30-3:2024, Table 4.

Justification

Table 23 supports the requirement in 5.9 which addresses minimum efficiency levels for high-voltage motors.

6 Site conditions

Add new subclause

6.8 Degree of ingress protection

The minimum degree of ingress protection for the motor shall be as specified in Table 24 and in accordance with IEC 60034-5.

Justification

The degree of ingress protection for motors is governed by the location of installation and the environmental conditions to which the motors are exposed, such as "indoor", "outdoor – onshore" and "outdoor – offshore (fixed/floating)". IEC 60034-5 adequately covers the protections taken against respective environmental conditions.

Add new Table 24

Table 24 – Minimum degree of ingress protection based on the location of the installation

Installation environment	Minimum degree of ingress protection	
	Motor	Terminal box
Indoor	IP55	IP55
Outdoor – coastal and onshore	IP55	IP55
Outdoor – offshore / open deck	IP56	IP56

Justification

This table lists the minimum degree of ingress protection used in the industry based on the location of installation of the motor. The individual parts on the motor such as the terminal box and bearing housing may have a higher degree of protection as required.

8 Thermal performance and tests

8.1 Thermal class

Replace first paragraph with

The motor insulation system shall be thermal class 155 (F) without exceeding thermal class 130 (B) temperature rise for the motor rated output at the maximum reference coolant temperature.

Justification

Insulation system class F, class B temperature rise is an industry-recognized cost-effective specification facilitating increased motor life by improved winding insulation quality. This insulation specification is acknowledged by manufacturers as the most commonly requested for industrial motors. Therefore, it is compliant with the minimum specification philosophy of JIP33. The use of class F insulation with class B temperature rise gives products a safety margin of 25 °C, allowing a life time longer than 20 000 h and aligning with ANSI/NEMA MG 1. This can be exploited to increase the loading of the machine for limited periods to operate at higher ambient temperatures or altitudes, or with greater voltage and frequency tolerances. It can also be exploited to extend insulation life. Manufacturers qualify insulation systems by means of functional tests as defined in IEC 60034-18-1:2022, 4.5.

Add to subclause

For converter duty motors, the motor insulation system shall be thermal class 155 (F) without exceeding thermal class 130 (B) temperature rise within the operating load envelope at the maximum reference coolant temperature.

Justification

This requirement defines the performance standard, for converter duty motors, which is commonly used throughout the industry, however IEC 60034-1 does not provide a performance requirement on temperature rise limits for converter duty motors. Manufacturers qualify insulation systems by means of functional tests as defined in IEC 60034-18-1:2022, 4.5.

8.6 Determination of winding temperature

8.6.1 Choice of method

Delete second paragraph (including NOTE)

Justification

It is common to use the resistance method for determination of the stator winding temperature for motors over 5 MW, therefore this paragraph introduces unnecessary restrictions to testing and is removed. The resistance method measures the average conductor temperature as opposed to the embedded temperature detector (ETD) which measures the temperature outside the main wall insulation (in an assumed hot spot area). The conductor temperature is higher than what the ETD is measuring. It is basically the hottest temperature in the winding that is of interest (determining the thermal lifetime of the winding), but this is not possible to measure. IEC 60034-1 allow a higher temperature rise by the ETD method compared to the resistance method, but if the resistance method (average conductor temperature) is giving a higher temperature rise than the ETD method, this does not make sense. The proposal to standardize the resistance method is based on experience and consistent with IOGP S-704, Version 1.0 comments.

Delete third paragraph

Justification

This paragraph has been deleted to ensure that there is no conflict in requirements as this is now covered by an optional requirement in IOGP S-704D.

8.6.2 Determination by resistance method

8.6.2.3 Correction for stopping time

8.6.2.3.2 Short stopping time

Replace first paragraph with

The short stopping time shall be determined by the following steps.

a) Obtain the initial resistance reading after stabilization of the measuring device and within 120 s of switching off power.

b) Take additional readings at 30 s intervals over a period of 5 min following the first reading.

c) Calculate the resistance value at the time of switching off power by means of extrapolation.

d) Use the resistance value at the time of switching off power to confirm the winding temperature.

e) Measure the resistance between the same windings for all readings.

Justification

This paragraph and Table 6 in IEC 60034-1 leaves room for inconsistency as the temperature value is accepted when measured within time delay in Table 6. The inconsistent results are due to a drop in the winding temperature between 5K and 10K when measured or extrapolated within 120 s after shut-down as compared to the value extrapolated to t = 0. The steps in this paragraph replacement standardize the procedure for measurement of winding resistance across suppliers and entire product range. This procedure makes the measurements comparable and accurate. Hence, this paragraph has been replaced and Table 6 has been deleted. This requirement aligns with IEC 60034-2-1:2024, 5.7.1, paragraph 5 for extrapolation to measure winding resistance at t = 0.

Table 6 – Time interval

Delete Table 6

Justification

The steps stated in this subclause of IEC 60034-1 leaves room for inconsistency as the temperature value is accepted when measured within time delay in this table. The inconsistent results are due to a drop in the winding temperature between 5K and 10K when measured or extrapolated within 120 s after shut-down as compared to the value extrapolated to t = 0. However, IEC 60034-2-1:2024, 5.7.1, paragraph 5 states a procedure which is revised to ensure extrapolation to measure winding resistance at t = 0. The steps in paragraph 1 of this subclause standardize the procedure for measurement of winding resistance across suppliers and entire product range. This procedure makes the measurements comparable and accurate. Hence, this paragraph has been replaced and Table 6 has been deleted.

8.6.2.3.3 Extended stopping time

Delete subclause 8.6.2.3.3

9 Other performance and tests

9.1 Routine tests

Add to subclause

A "soft foot" check in accordance with API Standard 541:2014, 6.3.1.16 shall be made prior to mechanical running tests.

Justification

The "soft foot" check ensures that the motor mounting is of a defined pre-agreed standard and that the mounting arrangement does not have an adverse effect on the results of the motor vibration test. This requirement aligns JIP33 with API Standard 541:2014, 6.3.1.16.

Add to subclause

For flooded lubrication systems, factory tests shall be carried out using the specified lube oil viscosity with the oil temperature maintained within the range of operating values recommended by the manufacturer.

Justification

This requirement ensures that testing parameters are as close to the operating conditions on site as possible. This excludes the possibility of using other parameters in the testing facility, either for convenience or to optimize testing results.

NOTE The terms "flooded lubrication" and "forced lubrication" may be used interchangeably.

Add to subclause

During vibration severity tests, the lube oil inlet temperature shall be adjusted to the maximum temperature permitted by the lubrication system design.

Justification

This requirement ensures that vibration levels are tested at the maximum lube oil temperature and that the recorded vibration values do not exceed maximum allowable levels. This requirement aligns in principle with API Standard 541:2014, 6.3.1.7.

Add to subclause

When bearing modification or replacement is undertaken during testing, bearing-related tests shall be repeated to reassess the bearing performance.

Justification

Bearing modification or replacement can affect the performance of the motor, whether adversely or positively. This requirement ensures that relevant tests are repeated to reassess the bearing performance after bearing modification or replacement has taken place.

Add new NOTE

NOTE Cosmetic repairs such as removal of scratches that do not otherwise affect motor performance are not a reason for retesting.

Replace Table 16 title with

Table 16 – Tests for motors assembled and tested in the manufacturer's factory

Replace Table 16 with

Test No.	Test description [i, j]	Reference standard	Remarks
Routine tests			
1	Visual inspection	Approved drawings and documents	
2 [f]	Measurement of ohmic resistance of stator windings referred to 25 °C	IEC 60034-2-1:2024, 5.7.1	
3	Measurement of insulation resistance of stator windings	IEC 60034-27-4	Test also carried out post withstand voltage test
4 [f]	Check of phase sequence/direction of rotation and terminal markings	IEC 60034-8:2014, 6.7	
5 [f]	No-load losses and current test at rated frequency [a]	IEC 60034-2-1:2024, 6.1.3.2.4	
5A	No-load losses and current test at minimum continuous operating speed	IEC 60034-2-3	Test for converter duty motor
5B	No-load losses and current test at maximum continuous operating speed	IEC 60034-2-3	Test for converter duty motor
6	Verification of magnetic centre and end play (where sleeve bearings are provided)	API Standard 541:2014, 4.4.9.3	
7 [f]	Withstand voltage test on stator windings	IEC 60034-1:2022, 9.2	
8	Measurement of insulation resistance of insulated bearings	IEEE 112:2017, 8.4	
9	Functional tests of auxiliary devices and controls	Manufacturer's standard	
10	Withstand voltage tests on resistance temperature devices (RTDs)	IEC 60034-1:2022, 9.2	
11	Insulation resistance tests on RTDs and space heaters where applicable	IEC 60204-1:2016, 18.3	
12	Vibration test at no load	IEC 60034-14:2018, Clause 8 and Clause 9	
13	Measurement of electrical and mechanical run-out (measured at slow roll speed between 200 rpm to 300 rpm)	API Standard 541:2014, 6.3.3, IEC 60034-14:2018, Clause 9	Refer to API Standard 541 for test procedure. Test not applicable for rolling element bearings
Performance tests [g]			
1	No-load characteristic (saturation curve) at rated frequency [b]	IEC 60034-2-1:2024, 6.1.3.2.4	
2	Locked rotor current test	IEEE 112:2017, 7.2	Test for single-speed motor
3	Locked rotor torque test	IEEE 112:2017, 7.2.2	Test for single-speed motor

Table 16 *(continued)*

Test No.	Test description [i, j]	Reference standard	Remarks
4	Temperature rise test	IEC 60034-1:2022, Clause 8 or IEC 60034-29 [c]	
5	Sleeve bearing inspection	API Standard 541:2014, 6.3.2	
6	Determination of efficiency, power factor and slip at 100 %, 75 % and 50 % load	IEC 60034-2-1:2024, Clause 6	Test for single-speed motor
6A	Determination of efficiency, power factor and slip at 100 %, 75 % and 50 % load	IEC 60034-2-3:2020, Clause 6	Test for converter duty motor
Special tests [h]			
1	Rated rotor temperature vibration test (heat run test)	API Standard 541:2014, 6.3.5.2	Alternately testing (procedure, purpose, etc.) to be agreed between purchaser and manufacturer
2	Overspeed test	IEC 60034-1:2022, 9.7	
3	Measurements of shaft voltage at no-load	IEEE 112:2017, 8.3	
4	Bearing temperature rise at no-load	API Standard 541:2014, 6.3.2	
5	Noise level at no load	ISO 1680	
6	Measurement of moment of inertia	Manufacturer's standard	
7	Measurement of torque and current as function of speed during starting	IEEE 112:2017, 7.3.2	
8	Dielectric dissipation test (tan δ) on stator windings	IEC 60034-27-3	Test performed with stator winding installed in frame
9	Partial discharge test on complete stator	IEC 60034-27-1, IEC 60034-27-2	Test performed with stator winding installed in frame
10	Sealed winding conformance test	ANSI/NEMA MG 1	In process test
11	Unbalanced response test	API Standard 541:2014, 6.3.5.3	
12	Bearing housing natural frequency test	API Standard 541:2014, 6.3.5.4	
13	Stator core test	API Standard 541:2014, 6.3.4.1	In process test
14	Surge comparison test (complete stator assembly)	IEEE 522	In process test
15	Sample coil test	API Standard 541:2014, 6.3.4.2, IEC 60034-15, IEC 60034-27-1, IEC 60034-27-3	
16	Heat exchanger performance verification test	API Standard 541:2014, 6.3.5.5	
17	Hydrostatic pressure test of heat exchanger tubing devices [d]	Design code [e]	
18	External discharge (Corona) test	IEEE 1799	

Table 16 *(continued)*

Test No.	Test description [i, j]	Reference standard	Remarks
[a] No stabilization of temperature required for measurement of no-load losses.			
[b] The no-load characteristic shall be measured up to a minimum of 125 % of the rated voltage.			
[c] IEC 60034-29 shall be used as the reference standard where testing to IEC 60034-1 is restricted due to the limitations of the test facilities.			
[d] Heat exchanger testing is performed at the heat exchanger manufacturer's premises.			
[e] Heat exchanger design code to be confirmed by the supplier.			
[f] Tests listed in the original table.			
[g] Where one or more than one identical motor is purchased, the listed performance tests are carried out on at least one motor. However, the need for the performance tests and the number of motors to be tested may be agreed between the purchaser and manufacturer.			
[h] The special tests required to be performed in IOGP S-704D shall be specified.			
[i] Motor shall be rigidly mounted in accordance with IEC 60034-14, 6.3 for mechanical tests.			
[j] Tests shall be performed with project-specific sensing, monitoring and protection devices mounted on the motor.			

Justification

The original Table 16 in IEC 60034-1 has minimal test requirements that cover all motors whereas the revised content of Table 16 has tests exclusively for high-voltage motors, including additional routine tests, as well as special tests specified by the purchaser.
For high-voltage motors in the oil and gas industry, special/additional tests are performed to verify that the required performance criteria are met prior to the machine leaving the manufacturer's premises due to the following reasons.

- *High-voltage motors are typically regarded as high value items.*
- *High-voltage motors are used in systems where, if they do not perform as required, it could have a severe financial consequence to the end user.*
- *In most cases, high-voltage motors are engineered equipment to some extent and therefore, all test criteria are verified before acceptance by the purchaser.*
- *Logistically, any remedial work required once the high-voltage motor is on site can be complex.*
- *These routine tests provide a performance benchmark that can be compared to test results post-installation at site and throughout the design life of the high-voltage motor.*

9.2 Withstand voltage test

In eighth paragraph, replace "7.3" with

7.4

Justification

This incorrect reference is a carryover from the previous edition where the reference was to subclause 7.3 which in the current edition is subclause 7.4. This is understood to be a typographical error.

9.4 Momentary excess torque for motors

9.4.1 Polyphase induction motors and DC motors

Delete seventh paragraph

Justification

For motors with a starting current between 4.0 and 4.5 times rated current, this specification allows for a minimum breakdown torque of 150 %. However, an argument that 80 % of motors do not have starting current between 4.0 and 4.5 times rated current does not help for the motor that have a starting current between 4.0 and 4.5 times rated current. Hence, it is preferred to delete this paragraph.

10 Information requirements

10.3 Rating plate

Replace first sentence of first paragraph with

Rating and marking plates shall be made from 316L stainless steel.

Justification

Stainless steel rating plates are a readily available standard offering and a proven solution to issues experienced using other methods. For example, industry experience shows that illegibility due to other types of marking plates causes problems such as delayed troubleshooting.

Replace second sentence of first paragraph with

The information included on rating and marking plates shall be stamped or engraved.

Justification

This is a common user requirement to prevent machine information from getting lost over time due to wear and tear. This is a tried, tested and proven industry practice which ensures that the information remains attached to the equipment during its operational life. Although this information is also made available in other associated documents of the equipment, the relevant information is available with the equipment. This requirement is included in most operator specifications but not stated in IEC 60034-1.

In first sentence of second paragraph, replace "The rating plate(s) shall preferably be mounted on the frame of the machine" with

The rating and marking plates shall be attached to a non-removable part of the motor frame with stainless steel 316L fasteners

Justification

As per 10.3, first sentence of first paragraph, this requirement ensures that the fasteners are of the same durability as the rating plate. By ensuring that the rating and marking plates are attached to a non-removable part, there is no chance of the part being mistakenly reattached to a different unit or misplaced during maintenance or breakdown activities.

10.4 Information content

10.4.1 General

In first sentence of first paragraph, replace "10.4.5" with

10.4.6

Justification

Subclause 10.4.6, named "Optional information" in IEC 60034-1, has been renamed "Additional information" in this specification and the list of items included in this subclause has now been added to the list of information to be provided as applicable (i.e. to the list of items subject to the requirement in 10.4.1). It is necessary to include information related to the cooling method, converter capability, torque capability, impulse voltage insulation class (IVIC) level and rated power factor on the rating plate specifically as these are more critical machines. Bearing and bearing lubrication information is required for bearing replacement on-site. This is beneficial on the nameplate when maintenance is being performed on site as there is no need to look for the documentation. The mixing of lubricants could damage a bearing.

Delete third sentence of first paragraph

Justification

The list items in 10.4.6 are optional in IEC 60034-1 and have been made additional in this specification. Hence, this requirement is now redundant and has been deleted.

In first sentence of second paragraph, replace "jj)" with

ll)

Justification

This requirement results from the addition of new list items kk) and ll) in 10.4.6.

10.4.2 Minimum information requirements

Replace list item j) with

j) Efficiency at full load.

Justification

The nameplate indicates the efficiency value achieved at full load during the factory acceptance test. The original text in this subclause 10.4.2, item j) specifies efficiency class (IE codes) for motors within the scope of IEC 60034-30-1 and IEC 60034-30-2. However, for high-voltage motors, Table 23 specifies the minimum efficiency values. Subclause 10.4.2, item j) is replaced to specify the efficiency value achieved at full load during the factory acceptance test as part of the minimum information requirements on the nameplate for the machines.

Replace list item k) with

k) The total mass of the motor.

Justification

This replacement provides the total mass of the motor for lifting operations and the assessment of the equipment/effort for lifting.

Replace subclause 10.4.6 title with

10.4.6 Additional information

Replace list item gg) with

gg) On a separate rating plate, the types of bearings, bearing sizes, clearance, bearing insulation, shaft and housing fit for drive end and non-drive end bearings, type of lubricant, lubrication interval, minimum and maximum allowable quantity of lubricant, and maximum and minimum oil temperature / pressure / flow rate for flooded lubricated bearings and oil viscosity.

Justification

This information on bearings is beneficial for maintenance staff during predictive/preventive maintenance activities and provides a means for instant and reliable verification while at site without the need for equipment documentation.

Add new list item kk)

kk) For motors used in hazardous areas, the equipment marking on a separate nameplate applied to Ex equipment and/or Ex components in accordance with IEC 60079 (all parts).

Justification

By marking the equipment in accordance with IEC 60079 (all parts), the manufacturer confirms that the equipment/components are manufactured, successfully tested and certified for use in accordance with the applicable requirements of the relevant standards.

Add new list item ll)

ll) Locked rotor current.

Justification

This information on locked rotor current is beneficial to be included on the name plate as an essential minimum information for replacement procurement in the event of missing equipment documentation.

11 Miscellaneous requirements

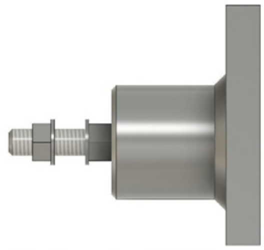
11.1 Protective earthing of machines

Replace fourth paragraph with

The machine shall have two diagonally opposite earthing bosses with M12 internal threads, fitted externally on the machine frame.

Justification

This requirement drives industry standardization on earthing externally. These earthing bosses are rounded metal parts with internal threads (typically M12) welded on the machine surface for external earth connections as per Justification Figure a and Justification Figure b.

Justification Figure a *Justification Figure b*

<u>*Add to subclause*</u>

The motor shall have a means for connecting a conducting cable sheath inside each terminal box.

Justification

This requirement drives industry standardization on earthing externally and internally. It also provides full optionality for instances where the machine is used in a different application.

<u>*Add to subclause*</u>

The earthing boss shall be permanently marked with the symbol ⏚ (IEC 60417-5019) to indicate protective earth.

Justification

This requirement is in line with the identification of components on the equipment in accordance with IEC 60417. The marking highlights the purpose of the component and prompts to leave clear access for termination/connection at site.

<u>*Add new subclause*</u>

11.3 Performance criteria

11.3.1 Single-speed motor starting, re-starting and re-acceleration

11.3.1.1

For motors without specific starting requirements, the locked rotor current shall be between 4,0 and 6,5 times the rated current.

Justification

Maximum starting currents are defined to ensure that electrical power systems are not adversely affected. This requirement ensures consistency in electrical supply design. It is acknowledged that the values may be higher for high-efficiency machines and this has been considered while developing the requirement. Establishing the locked rotor current of the motor enables the motor cable sizing and ensures that the upstream/downstream busbars do not experience excessive under voltage during motor starting. 4,0 to 6,5 times the rated current has been defined as this value can be generally complied with by manufacturers as their standard offering, and this upper limit value also corresponds to API Standard 541:2014, 4.2.4.4.

11.3.1.2

The motor shall be designed for direct-on-line starting across full line voltage in accordance with Table 25.

Justification

When a motor is subjected to frequent starting, it cannot be loaded at its rated output because of thermal starting losses in the windings. Table 25 establishes the minimum requirements to ensure consistency for these parameters across the industry. These parameters are the current industry standard and compliance with these is already the norm.

Add new Table 25

Table 25 – Number of re-starts of motors

Starting condition	Status	Minimum number of consecutive starts [a] per hour
With the initial temperature at or below the maximum ambient temperature	Cold	3
With the initial temperature above the maximum ambient temperature but not exceeding the maximum rated operating temperature	Hot	2
[a] The motor should coast to rest between consecutive starts.		

Justification

When a motor is subjected to frequent starting, it cannot be loaded at its rated output because of thermal starting losses in the windings. Minimum requirements are specified to ensure consistency for these parameters across the industry. These parameters are the current industry standard and compliance to these is already the norm. The values in the table are the current industry norm.

11.3.1.3

Motors shall be designed and constructed for a lifetime minimum of 5 000 full voltage starts.

Justification

Though 1 000 starts per year is the industry standard and provides assurance on the design life of the motor, such a requirement does not qualify to be an essential minimum requirement. Such large motors are not started/stopped so frequently and do not need these severe design requirements. 1 000 starts per year is almost 3 starts per day and typically impractical for such rating motors in oil and gas industry. With motors designed for 5 000 starts in lifetime, one start in two days would span over 27 years which is more than the desired service life of the motor. This is a more practical approach in line with API Standard 541:2021, 4.2.4.1 and is considered a better essential minimum requirement for motor design.

11.3.1.4

The motor shall start direct-on-line and accelerate with the rated load at 80 % of the rated voltage applied at the motor terminals.

Justification

The 80 % value allows for upstream system deviations and voltage drop in conductors from the point of supply to the motor location typically incurred in the oil and gas industry. The 80 % value is particularly prevalent in island networks and also aligns with API Standard 541:2014, 4.2.3.1.

11.3.1.5

The locked rotor withstand time under hot condition shall be greater than the time required to accelerate the specified driven load at 80 % of rated voltage at the motor terminals plus 5 s.

Justification

This requirement ensures that there is a sufficient amount of time between the acceleration time of the specified load and the locked withstand time under hot condition. This margin adequately ensures that the motor protection devices operate and isolate the motor prior to damage occurring due to overheating of motor windings.

11.3.1.6

Inclusive of the negative tolerance, the accelerating torque of the motor at the rated frequency with 80 % of the rated voltage applied at the motor terminals shall be at least 10 % of the full load torque at any point.

Justification

This requirement provides assurance that there is a defined margin between the load requirements and the capability of the motor to ensure that the torque at the driven load is sufficient.

11.3.1.7

Running-up times shall be calculated using inertia values and torque-speed characteristics of the driven equipment.

Justification

Running-up time can typically be calculated using either approximation methods or actual values for load inertia and driven equipment torque-speed characteristics. For high-voltage motors that are typically high value equipment installed in critical systems, the actual values are used to ensure accuracy.

11.3.2 Transient air-gap torques

The rotor shaft and active iron core systems shall withstand a two-phase short-circuit current at the motor terminals for 0,2 s.

Justification

This requirement addresses the capability of the rotor shaft and active iron systems to withstand a two-phase short-circuit current which is considered to be the most adverse fault type. This is a fundamental requirement that is not addressed in IEC 60034-1.

11.3.3 Pulsating torques

The inertia of the motor driving equipment requiring variable torque during each revolution shall restrict the stator current variation to 40 % of the motor rated current.

Justification

This requirement ensures that there is sufficient inertia present in the rotor and the shaft to maintain rotation where there is variable torque such that the stator current does not exceed 40 % of the full load current. It ensures that unnecessary overheating of the motor does not occur. This ultimately reduces the design life of the motor and can cause reliability issues due to overheating that causes harm to the winding insulation. This requirement aligns with API Standard 618.

11.3.4 Critical speed

11.3.4.1

For single-speed motors, the lateral natural frequencies that result in resonance amplification of vibration amplitudes shall fall outside the band of operating speed ± minimum 15 %.

Justification

Rotating shafts deflect during rotation. The mass of the rotating object causes deflection that creates resonant vibration at certain speeds known as the critical speeds. If the speed, as a result of the forced surge frequency, is the same as the lateral natural frequency of the system, resonance can occur.
The magnitude of deflection depends upon the following:

- *stiffness of the shaft and its support;*
- *total mass of shaft and attached parts;*
- *balance of the mass with respect to the axis of rotation;*
- *amount of damping in the system;*
- *foundation design of motor mounting area.*

In view of these influencing parameters, this requirement ensures that the lateral natural frequencies fall outside the safe band enveloping the operational speed and that the measurable margin is defined as 15 %, which is adequately distant to not cause resonance.

NOTE Well-damped resonances with an amplification factor less than 2.5 are not considered critical speeds.

11.3.4.2

For converter duty motors, the lateral natural frequencies that result in resonance amplification of vibration amplitudes shall fall outside the band of operating speed range ± minimum 15 %.

Justification

Converter duty motors stabilizing at many speeds throughout the operating envelope are more likely to encounter critical speeds than a single-speed motor. To prevent resonance and thereby vibrations, this requirement ensures that the lateral natural frequencies or the critical speeds fall outside the entire operational speed range and that the safe margin practically is ± minimum 15 % as per industry practice.

11.3.4.3

When motors with sleeve bearings pass through a critical speed during starting or stopping, the peak-to-peak amplitude of vibration levels within ± 15 % of the critical speed shall be less than 75 % of the nominal bearing clearance.

Justification

Resonance is caused when the forcing frequency coincides with the natural frequency of the rotor system, which results in high vibration of the rotor. While utmost care is taken during design, the motor accelerating towards the operating speed could coincide with natural frequency of the rotor system and cause vibration. Resonance is not often a concern when motors operate at their design speed. Even if a natural frequency resides between zero and full speed, it is passed quickly during starting and stopping. However, depending on the number of motor poles (synchronous speed), the time to pass through this critical speed range could be from one second to a few seconds. Though it seems like a harmless passing event, operators have experienced failures/damages resulting in excessive downtime. It justifies this requirement as essential. The boundary value in the requirement text standardizes the acceptance criteria across suppliers.

11.3.5 Noise

11.3.5.1

The sound pressure level of the machine operating at rated speed and no load when fed with sinusoidal supply voltage, measured in any direction at a distance of 1 m, shall be less than 85 dB(A).

Justification

Noise regulations are part of health and safety at the workplace in industry and are legally binding, especially by countries as part of the national law. Limiting the noise level to which operating personnel are exposed reduces the harmful effects of noise on hearing. The permissible maximum noise level value along with the use of hearing protection corresponding to a daily or weekly average noise exposure is typically restricted to 85 dB(A). Considering the rating and size of the machines, if an upper limit is not specified, the noise from the equipment can cause detrimental effect to operating personnel. ISO 1680, Clause 4 indicates that rotating electrical machines can be fed by network supply (sinusoidal) or a converter. Though the scope of this specification also covers converter duty motors, the testing conducted with sinusoidal supply is the normal practice.

11.3.5.2

Motors shall meet the noise limits by design without implementing noise abatement measures.

Justification

Noise abatement measures can camouflage machine deficiencies and seem to have fulfilled the stated noise limit requirement. The exclusion is explicitly stated as these noise abatement measures can have an undesirable effect on the performance of the motor and impede access during maintenance activities.

NOTE Noise abatement measures implemented to meet the noise limits are indicated on the drawings for approval by the purchaser.

Justification

It is important to know the noise abatement measures being adopted by suppliers as part of their design and be acceptable. Some measures adopted do not last enough or deteriorate over time and defeats the compliance/ intent of the requirement. Representing these measures on the drawings is useful to accept the design or suggest/request for alternate acceptable measures.

11.3.5.3

Noise measurements shall be in accordance with ISO 1680.

Justification

ISO 1680 is the recognized reference for noise measurement by most manufacturers and for noise requirements in the oil and gas industry. This requirement ensures consistency going forward, especially with new manufacturers.

Add new subclause

11.4 Design criteria

11.4.1 General

11.4.1.1

The motor shall be designed and constructed for a minimum service life of 25 years excluding parts subjected to wear and tear.

Justification

The motor is expected to provide a minimum useful service life of 25 years in the specified environmental conditions. However, the expectation of minimum useful service life considers that the manufacturer's recommended maintenance activities are performed as per the maintenance plan. High value assets such as the motor include an expected service life as part of the asset integrity plan.

11.4.1.2

The motor shall be designed for continuous operation of at least six years.

Justification

Operating companies may have a turnaround period ranging from four to six years and motors are expected to operate without interruption for this duration. Major scheduled maintenance is an activity that is performed during the turnaround time that further extends the period of operation and provides an expected service life of 25 years. However, oil change of self-lubricated sleeve bearings is an activity that needs to be performed as per the supplier's recommendations to ensure the expected service life of the bearings.

NOTE Interim maintenance like lubricant replacement and filter cleaning at intervals recommended by the manufacturer may be required to achieve the continuous operation period.

11.4.1.3

The motor shall be constructed with components, materials and design features that have proven service in the industry for at least two years.

Justification

This requirement ensures that the motors provided are proven in use, or if not proven, additional steps, measures or activities to be undertaken. Typically, this is not an issue, but there is nowhere else in this specification that causes the manufacturer to make the purchaser aware of this.

11.4.2 Enclosure design

11.4.2.1 General

11.4.2.1.1

The motor enclosure shall have a low point drain hole with a removable plug.

Justification

Typically, drain holes are provided in the enclosure of motors for egress of moisture/condensation from within the housing. These drain holes have removable plugs and following the manufacturer's guidelines, they ensure that the degree of ingress protection is maintained.

NOTE Ex-db motors are exempted from this requirement.

11.4.2.1.2

Drain plugs shall be accessible with the motor installed in service position.

Justification

This requirement facilitates maintenance activities associated with draining the motor without dismantling any of the parts or components. In some cases, this can require the removal of the coupling guard for ease of access.

11.4.2.2 Mounting

11.4.2.2.1

The motor mounting arrangement shall be in accordance with IEC 60034-7.

Justification

The reference to IEC 60034-7 is for the most commonly used mounting methods across suppliers and in industry-wide applications. This requirement standardizes the definition of mounting and provision for installation on the baseplate for driven equipment. It also ensures that motors can be replaced and upgraded. The choice of mounting is as per application / driven equipment specifications and manufacturers' design needs.

11.4.2.2.2 Vertically-mounted motors

11.4.2.2.2.1

Vertically-mounted motors with a downward facing drive end shaft shall be provided with a canopy shielding the upward facing air inlets.

Justification

This requirement ensures that the possibility of water/fluid ingress from around the motor shaft area is fully addressed when motors are vertically mounted and air inlets are upward facing. The canopy (rain cap) fitted over the fan cowl / air inlets of motors mounted with the shaft vertically down prevents rain water or any sprayed water/fluid from reaching the area near the motor shaft, thereby preventing the water/fluid from following the minor clearance around the motor shaft into the motor. A seepage of water/fluid causes failure of the part (bearing, winding, etc.) that gets exposed to water/fluid.

11.4.2.2.2.2

Vertically-mounted motors with an upward facing drive end shaft shall be provided with a seal in addition to the bearing seal and/or shaft-mounted water flinger to prevent water/fluid ingress through the drive end bearing.

Justification

This requirement ensures that the possibility of water/fluid ingress from around the motor shaft area is fully addressed when motors are vertically mounted and the shaft is facing upwards. The seal / water flinger (water deflector) fitted over the drive end shaft of motors mounted with the shaft vertically up prevents rain water or any sprayed water/fluid from reaching the area near the motor shaft, thereby preventing the water/fluid from following the minor clearance around the motor shaft into the motor. A seepage of water/fluid causes failure of the part (bearing, winding, etc.) that gets exposed to water/fluid. This requirement addresses operating company experiences where water has accumulated on the face of the upward facing bearing and has over time prematurely deteriorated the bearing seal, causing failure and subsequent interruption of service.

11.4.2.2.3 Mounting surfaces and alignment

11.4.2.2.3.1

Mounting surfaces shall be machined to a finish of at least 6,3 µm arithmetic average roughness (Ra).

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. a). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.2

Mounting surfaces shall be machined within a flatness of 40 µm per linear meter of mounting surface.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. c). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.3

Mounting surfaces shall be in the same horizontal plane within 125 µm.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. b). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.4

The upper machined or spot faced surface shall be parallel to the mounting surface.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. f). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.5

Mounting planes shall be parallel to each other within 0,17 mm per metre.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. d). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.6

Horizontal motor mounting planes shall be parallel to the horizontal plane through the bearing centreline within 0,17 mm per metre.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. e). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.7

The mounting surface on a vertical motor shall be machined perpendicular to the centreline of the motor.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.9. For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.8

The mounting surface on a vertical motor shall not deviate from the perpendicular plane by more than 0,17 mm per metre.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.9. For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.9

Hold-down bolt holes shall be drilled perpendicular to the mounting surfaces of the motor.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. g). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.10

Hold-down bolt holes shall be machined or spot faced to a diameter of at least three times that of the bolt hole.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.10. For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.11

Hold-down bolt holes shall be 13 mm larger in diameter than the hold-down bolt.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. g). Due to the extra-large clearance hole (13mm larger), it provides the motor with more flexibility to align. The alignment can be done with the hold down bolt in its extreme position where the bolt is touching one side of its clearance hole. To support the mounting, load bearing washers needs to be provided. For high-voltage motors it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.12

Load-bearing washers shall remain in 360° contact with the mounting faces when the machine is aligned in its extreme position where the bolt is touching one side of its clearance hole.

Justification

This requirement ensures a minimum criteria for frame mount surface in accordance with API Standard 541:2014, 4.4.2.8. g). For high-voltage motors, it is critical to have this addressed to provide required performance throughout the design life of the motor. This basic requirement contributes to the successful performance of the motor from initial set-up through the complete design life of the motor.

11.4.2.2.3.13

Frame supports shall be provided with two vertical pilot holes for the installation of alignment dowels.

Justification

This requirement provides an efficient method for future motor alignment following initial alignment. Once the initial alignment has been successfully completed, the dowels can be installed to facilitate a fast method of locating the motor. This is as per API Standard 541:2014, 4.4.2.11.

11.4.2.3 Frame

11.4.2.3.1

Frame numbers and fixing dimensions shall be in accordance with IEC 60072-2.

Justification

This requirement reduces variants and ensures that any motor outside of the scope of IEC 60072-2 is assessed by the purchaser to ensure that it is acceptable prior to order placement. Any design outside of the scope of IEC 60072-2 is likely to be unproven and/or can have characteristics or features for which the purchaser requires more information before order placement.

11.4.2.3.2

The motor frame and add-on assemblies inclusive of terminal box covers heavier than 25 kg shall be provided with lifting lugs or lifting eyebolts.

Justification

This requirement facilitates safe lifting for installation, removal and refitting of the equipment and heavier frame-mounted add-on assemblies including terminal boxes and terminal box covers. Without this requirement, non-compliance with HSE norms followed in the industry can happen.

11.4.2.3.3

Foot-mounted motors shall be provided with vertical jacking provisions and, when a soleplate is included in the scope of supply, with horizontal jacking provisions.

Justification

This requirement enables a safe and standard means of alignment of the motor with the coupled equipment during installation.

11.4.2.3.4

Where a corrosivity category of C4 or greater is specified, the selection of hardware used on the frame shall be in accordance with Table 26.

Justification

ISO has defined six corrosivity categories (i.e. C1 - very low, C2 - low, C3 - medium, C4 - high, C5 - very high, CX - extreme) based on a one-year corrosion mass loss or penetration of steel, zinc, copper and aluminium coupons. Environmental conditions contribute directly to the occurrence of corrosion and are therefore accounted for in this specification. The effects of corrosion and the rate at which they occur are consequences of the choice of material, exposure to environmental conditions (both severity and duration) and operational conditions. Where a category greater than C3 is specified, the selection of hardware is done in accordance with these environment conditions to meet the life cycle requirements. This requirement ensures that the equipment can withstand the environmental conditions and meet the life cycle requirement. Table 26 compiles a preferred selection of material from most manufacturers for corrosivity category of C4 or greater.

Add new Table 26

Table 26 – Selection criteria for hardware used on frame

Hardware type	Hardware material
External screws, bolts, nuts and washers of a thread diameter less than or equal to 10 mm	316L stainless steel
External screws, bolts, nuts and washers with a thread diameter greater than 10 mm	Hot-dip galvanized
Cooling air inlet protection mesh	316L stainless steel
Grease nipples	316L stainless steel

Justification

ISO has defined six corrosivity categories (i.e. C1 - very low, C2 - low, C3 - medium, C4 - high, C5 - very high, CX - extreme) based on one-year corrosion mass loss or penetration of steel, zinc, copper and aluminium coupons. Environmental conditions contribute directly to the occurrence of corrosion. The effects of corrosion and the rate at which they occur are consequences of the choice of material, exposure to environmental conditions (both severity and duration), and operational conditions. This table considers environmental factors in the selection of hardware in order to meet the life cycle requirements. It also compiles a preferred option of material from most manufacturers for corrosivity category of C4 or greater.

11.4.2.3.5

Motors with a frame size 630 and above shall have removable inspection covers for the following:

– where applicable, inspection of coil end turns;

– inspection of air gap in at least three positions located 90° apart.

Justification

This requirement substantially reduces the time taken to perform the routine inspection by providing designated borescope inspection facilities for the inspection of the air gap and coil end turns as applicable. It also ensures that inspection can be performed throughout the lifetime of the motor, which facilitates the early detection of abnormalities and corresponding proactive corrective actions to reduce downtime. This requirement also provides alignment with API Standard 541:2014, 4.1.10.

NOTE The provision of inspection covers is not possible in all situations and deviations, if any, are brought to the attention of the purchaser.

11.4.2.3.6

The frame of the assembled motor shall be free from structural resonance between 40 % and 60 % range of the operating speed.

Justification

Structural resonance is caused when the forcing frequency in an assembled machine coincides with the natural frequency of the structural frame, which results in high vibration of the frame. This is not an issue with cast frames but it has been a problem for larger machines with fabricated frames. The design ensures that the natural frequency of the assembled machine system does not coincide with the natural frequency of the frame between 40 % and 60 % range of the operating speed and differ by at least ±15 % from one and two times the running-speed frequency and by at least ±15 % from one and two times the electric power frequency. During the design stage, finite element analysis (FEA) can be performed on the fabricated frame design to verify that structural resonances are kept away from 0,5x operating speed. If FEA shows resonance on one or more of the above conditions and in the range mentioned, the frame design can be modified to move the resonance outside of this range. This helps the frame to achieve an infinite fatigue life due to the forcing frequencies where the peak vibration occurs. The FEA report can be reviewed during the factory acceptance test (FAT), or more commonly, the purchaser accepts the declaration that the FEA results confirm that the frame design is compliant. Operators have experienced failures/damages to the motor frame as well as to terminations (cable glands). This requirement text standardizes the design criteria across the suppliers.

11.4.2.3.7

The frame of the assembled motor shall be free from structural resonance within ± minimum 15 % around speed frequency, twice speed frequency, power frequency and twice power frequency.

Justification

Structural resonance is caused when the forcing frequency in an assembled machine coincides with the natural frequency of the structural frame, which results in high vibration of the frame. This is not an issue with cast frames but for larger machines with fabricated frames, it has been a problem. The design ensures that the natural frequency of the assembled machine system does not coincide with the natural frequency of the frame between 40 % and 60 % range of the operating speed and differ by at least ±15 % from one and two times the running-speed frequency and, by at least ±15 % from one and two times the electric power frequency. During the design stage, FEA can be performed on the fabricated frame design to verify that structural resonances are kept away from 0,5x operating speed. If FEA shows resonance on one or more of the above conditions and in the range mentioned, the frame design can be modified to move the resonance outside of this range. This helps the frame to achieve an infinite fatigue life due to the forcing frequencies where the peak vibration occurs. The FEA report can be reviewed during the FAT, or more commonly accept the declaration that the FEA results confirm that the frame design is compliant. Operators have experienced failures/damages to the motor frame as well as to terminations (cable glands).This requirement text standardizes the design criteria across the suppliers.

11.4.2.3.8

The magnitude of the vibration on the motor frame, including the main terminal boxes, excluding the bearings, shall not exceed 4,5 mm/s (RMS) in any direction.

Justification

Structural resonance is caused when the forcing frequency in an assembled machine coincides with the natural frequency of the structural frame, which results in high vibration of the frame. This is not an issue with cast frames but for larger machines with fabricated frames, it has been a problem. The design ensures that the natural frequency of the assembled machine system does not coincide with the natural frequency of the frame between 40 % and 60 % range of the operating speed and differ by at least ±15 % from one and two times the running-speed frequency and, by at least ±15 % from one and two times the electric power frequency. During the design stage, FEA can be performed on the fabricated frame design to verify that structural resonances are kept away from 0,5x operating speed. If FEA shows resonance on one or more of the above conditions and in the range mentioned, the frame design can be modified to move the resonance outside of this range. This helps the frame to achieve an infinite fatigue life due to the forcing frequencies where the peak vibration occurs. The FEA report can be reviewed during the FAT, or more commonly accept the declaration that the FEA results confirm that the frame design is compliant. This 4,5 mm/s RMS as the limit for vibration has been in the purchase specification of multiple operators since long without any pushback from the suppliers. Operators have experienced failures/damages to the motor frame as well as to terminations (cable glands). This requirement text standardizes the design criteria and defines the upper limit for the vibration on the motor frame along the axis of the shaft centerline as the acceptance criteria across the suppliers.

11.4.2.4 Surface finish

11.4.2.4.1

For onshore applications, the protective paint system corrosivity category shall be at least C3 in accordance with ISO 12944-2.

Justification

This requirement specifies the surface finish in relation to the environmental conditions in which the motor is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. ISO 12944-2 defines corrosivity categories and these definitions align with several manufacturer’s options. C3 as the default choice for onshore applications in the PDS sets the essential minimum requirement for the equipment across suppliers.

11.4.2.4.2

For offshore exterior applications, the protective paint system corrosivity category shall be CX in accordance with ISO 12944-2.

Justification

This requirement specifies the surface finish in relation to the environmental conditions in which the motor is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-2 in the PDS for the selection of the appropriate protective paint system. ISO 12944-2 defines corrosivity categories and these definitions align with several manufacturer's options. C3 as the default choice for onshore applications and CX as the default choice for offshore exterior applications in the PDS sets the essential minimum requirement for the equipment across suppliers. A higher option is selectable depending on environmental conditions. CX for offshore is aligned with IOGP S-715.

11.4.2.4.3

The protective paint system durability category shall be at least "medium" in accordance with ISO 12944-1 for all locations.

Justification

This requirement specifies the surface finish in relation to the environmental conditions in which the motor is located and drives standardization among operating companies. Therefore, it allows the purchaser to specify environmental conditions from the listed categories in accordance with ISO 12944-1 in the PDS for the selection of the appropriate protective paint system. For durability, "medium" is the default option as this is considered the lowest reasonable selection for the oil and gas industry (both onshore and offshore) and aligns with the default offering from most manufacturers. More onerous options are available in the PDS, if required.

11.4.3 Cooling

11.4.3.1 General

11.4.3.1.1

Motor cooling shall be selected from the cooling methods listed in Table 27, in accordance with IEC 60034-6 and the specified degree of ingress protection.

Justification

Limiting the method of cooling to Table 27 ensures consistency, provides alignment with IEC 60034 (all parts) and drives standardization among motor manufacturers.

Table 27 – Motor cooling method

Cooling method	Code
Frame surface cooled motors using surrounding medium with self-circulation of secondary coolant	IC4A1A1
Motors with an integral heat exchanger using surrounding medium with self-circulation of secondary coolant	IC5A1A1
Motors with a machine-mounted heat exchanger using surrounding medium with self-circulation of secondary coolant	IC6A1A1
Motors with a machine-mounted heat exchanger using remote medium with self-circulation of primary coolant	IC7A1W7
Motors with a machine-mounted heat exchanger using surrounding medium with self-circulation of primary coolant	IC8A1W7

Justification

Limiting the method of cooling to Table 27 ensures consistency, provides alignment with IEC 60034 (all parts) and drives standardization among motor manufacturers.

11.4.3.1.2

The operating frequency, or frequencies for converter duty motors, and operating frequency multiples of the motor shall not trigger the natural frequency of vibration of any cooling system components.

Justification

The cooling components could be add-on components (e.g. heat exchanger, externally mounted fans). This requirement ensures that the natural frequency of any add-on components is not triggered by the operating frequency or its multiples, resulting in unwarranted vibration and damages (e.g. cracks and/or breakages to the motor).

11.4.3.2 Air-cooled heat exchangers

11.4.3.2.1

Cooling air tubes shall be accessible for cleaning without removal of the exchanger assembly.

Justification

Regular cleaning of cooling tubes is important to maintain the heat removing capability. Restriction to access or any cumbersome means to access the exchanger tube ends prevents regular cleaning, thereby posing inadequate cooling and the possibility of failure.

11.4.3.2.2

A three-wire Pt-100 temperature sensor shall be provided to monitor the heat exchanger outlet air temperature.

Justification

This requirement provides a temperature monitoring facility that alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and machine damage can be minimized.

11.4.3.2.3

Air-cooled heat exchangers shall be in accordance with API Standard 541:2014, 4.4.10.8.

Justification

API Standard 541:2014, 4.4.10.8 adequately covers the selection of tube material for the exchanger design.

11.4.3.3 Water-cooled heat exchangers

11.4.3.3.1

Water-cooled heat exchangers shall be provided with low point drains and air release vents.

Justification

This requirement ensures that maintenance can be performed with minimal disruption/outage time and coolant sampling can be done, if required. The low point drains also ensure that the entire cooling medium is drained out of the system, which helps to flush the system. This air release facility is imperative for releasing the trapped air from the cooling system when topping up with the cooling medium.

11.4.3.3.2

Water-cooled heat exchangers shall have provision for leakage or condensation collection and drainage of coolant.

Justification

While it is acknowledged that water leakage should not occur, it is accepted that from time to time, water leakage can be possible. This requirement addresses the need for a secondary defence to prevent the water from coming into contact with vulnerable motor components, and for the water to be contained within a designated area. This facilitates the identification of any leakages and provides a facility for removing the leaked coolant in a controlled manner. This requirement helps prevent aggravated failure and ultimately prolonged equipment outages.

11.4.3.3.3

Water-cooled heat exchangers shall be provided with 20 % spare tubes.

Justification

This requirement provides additional capacity to allow for failure of tubes over the design lifetime of the machine. Replacing damaged tubes can in some cases be a complex process that requires a complete outage of the heat exchanger and therefore of the machine. By providing spare capacity (tubes) to allow for plugging of damaged tubes, the machine can continue to operate with minimal disruption for extended periods of time with the same cooling capability. This requirement uses 20 % spare tubes instead of 10 % since the repair/replacement of tubes is cumbersome, costlier and impractical (at times) when compared to providing an additional 10 % spare tubes by default. The probability of the need for undertaking a repair/replacement of tubes of the exchanger becomes remote when 20 % spare tubes are provided since the failed tubes can be plugged and forgotten as there are adequate spares. This spare quantity would generally last for the life cycle of the exchanger. Providing 20 % spare tubes does not impact the exchanger size and is a preferred alternative for reducing exchanger repair/maintenance over the life cycle.

11.4.3.3.4

Water-cooled heat exchanger tube bundles shall have provisions for plugging and isolating the leaking tubes.

Justification

This requirement ensures faster resolution of leakage problems since replacing damaged tubes can in some cases be a complex process that requires a complete outage of the heat exchanger and therefore of the machine. By plugging and isolating the damaged tubes, the machine can continue to operate with minimal disruption for extended periods of time.

11.4.3.3.5

Water-cooled heat exchangers shall be in accordance with API Standard 541:2014, 4.4.10.8.

Justification

API Standard 541:2014, 4.4.10.8 adequately covers the selection of tube material for the exchanger design.

11.4.3.3.6

When the required parameters on the water side are not available from the purchaser, cooling water system design criteria shall be in accordance with API Standard 541:2014, 4.4.1.2.4.

Justification

There could be a situation when the required parameters for the exchanger design are not available and the fall back is the parameters of API Standard 541:2014, 4.4.1.2.4. This requirement sets common default criteria instead of an arbitrary chosen value for manufacturers in the absence of a required value.

11.4.4 Stator windings

11.4.4.1

Winding coils shall be of copper and form-wound, global vacuum pressure impregnated (VPI) construction.

Justification

Form-wound designs are desirable for medium-voltage and high-voltage applications wherein the ability to provide better turn-to-turn insulation and greater mechanical strength results in a more reliable motor with relatively minor sacrifices in performance and cost. Applications that use continuous, repeated surge loads to the motor are usually best served with form-wound design. The surge loads result in magnetic reactions in the windings, particularly in the end turns of the stator, which tend to deform the windings or even break them over time. With a rigid, heavily braced design in case of form winding, the impact of these mechanical stresses can be more easily mitigated. The VPI process provides an insulation system with high dielectric strength, mechanical resilience, chemical and moisture resistance, and good thermal capabilities. Also, the solvent-free resins used in the VPI process are the non-reactive components of the formulation that have a very high initial boiling point and non-inflammable properties, making the formulation safer.

11.4.4.2

Winding coils shall be insulated by mica tape.

Justification

Mica is a natural mineral characterized by its thin peeling nature. Mica has excellent water-resistant properties, extremely high electrical insulation properties, including corona resistance and heat resistance, and is widely used as an electrical insulation material. Mica hardly causes any smoke, odour or any deterioration of strength or insulation resistance when heated to high temperature. Mica tape is made of mica paper and glass cloth bonded with epoxy resin. It has good resin impregnation properties, and most suited to building an insulation system by VPI method for high-voltage winding coils. Such tapes are highly flexible and easy to wind on coils, and provide good insulation between slot cells and coils and between layers of winding coils.

11.4.4.3

For motors with a rated voltage of 3 kV and above, windings shall be provided with an anti-corona protection system in the slot of the coil.

Justification

Electric field grading or field stress grading is the technique of effective and reliable distribution of the electric field within or around the winding coils. A reliable field stress grading system prevents partial discharge in the air gaps between the surfaces of winding coils and the winding ends / overhang region. These areas have increased electric field leading to corona discharges or partial discharges. Partial discharges deteriorate the winding insulation system, leading to failures of motor windings. The field stress grading systems cater to two parts namely the slot area using a conductive armour tape and the winding overhang region using a stress grading tape. The conductive armour tape used is made of carbon black embedded in a fibre-glass tape and prevents slot discharges. The stress grading tape is a semi-conductive tape made of finely woven polyester glass fabric impregnated evenly with an electrically semi-conductive varnish containing silicon carbide. These tapes are suitable for the main wall insulation and overhang of high-voltage winding coils and bars using VPI and resin rich technology. The reliability of the field stress grading system in the winding overhang region is important to the life of insulation due to the high electrical stress and the proximity of adjacent winding coils.

11.4.4.4

For motors with a rated voltage of 6 kV and above, field stress grading tape shall be used for anti-corona protection.

Justification

Electric field grading or field stress grading is the technique of effective and reliable distribution of the electric field within or around the winding coils. A reliable field stress grading system prevents partial discharge in the air gaps between the surfaces of winding coils and the winding ends / overhang region. These areas have increased electric field leading to corona discharges or partial discharges. Partial discharges deteriorate the winding insulation system, leading to failures of motor windings. The field stress grading systems caters to two parts namely the slot area using a conductive armour tape and the winding overhang region using a stress grading tape. The conductive armour tape used is made of carbon black embedded in a fibre-glass tape and prevents slot discharges. The stress grading tape is a semi-conductive tape made of finely woven polyester glass fabric impregnated evenly with an electrically semi-conductive varnish containing silicon carbide. These tapes are suitable for the main wall insulation and overhang of high-voltage winding coils and bars using VPI and resin rich technology. The reliability of the field stress grading system in the winding overhang region is important to the life of insulation due to the high electrical stress and the proximity of adjacent winding coils.

11.4.4.5

Winding coils and terminals shall have uniform insulation levels throughout the winding length.

Justification

This requirement ensures that the insulation thickness is consistent throughout the stator windings all along its length, otherwise it may be argued that the insulation level is met just by demonstrating its thickness at a single location and may not be consistent at another location.

11.4.4.6

Winding coils shall be tightly wedged in stator slots prior to vacuum pressure impregnation.

Justification

Current through the stator windings create lot of electromagnetic forces during steady state and transient operation. If windings are not tightly wedged prior to VPI, these forces cause movement, abrasion and premature failure of the stator winding insulation system. Moreover, such inadequately tight wedges remain unnoticed after VPI until a failure occurs.

11.4.4.7

The stator winding system including end windings, connections and circuit rings shall be securely and uniformly supported and braced in the radial and circumferential directions.

Justification

Current through the stator windings creates a lot of electromagnetic forces, especially on the free hanging ends of stator winding . These forces cause end winding movement which damages the winding insulation. The likelihood of damage increases as the insulation ages and becomes more brittle. Rigid supports and uniform bracing prevent excessive movement of end windings during steady state operation, motor starting and power system transients.

11.4.4.8

The terminal lead extensions from the stator winding to the terminal box shall be braced and supported securely in a manner that allows for thermal expansion and movement during starting, and prevent chafing.

Justification

Current through the terminal lead extensions creates electromagnetic forces on the leads during starting and power system transients. The leads also experience vibration forces during normal operation. These forces cause terminal lead movement which can damage some of the lead insulation. The likelihood of damage increases as the insulation ages and becomes more brittle. Since one end of the terminal leads is connected to the stator core assembly and the other end is connected to the terminal box, the leads experience differential movement as the stator core assembly experiences thermal expansion and contraction. The design of the terminal leads coupled with the method of supporting and bracing the terminal leads needs to prevent chafing and withstand this differential movement to prevent insulation cracking and failure.

11.4.4.9

The terminal lead extensions from the stator winding to the terminal box shall be insulated, and separated from terminal leads and surfaces of different potential.

Justification

Current through the terminal lead extensions creates electromagnetic forces on the leads during starting and power system transients. The leads also experience vibration forces during normal operation. These forces cause terminal lead movement which can damage some of the lead insulation. Additionally, the terminal leads when uniformly spaced and supported prevents movement of terminal lead extensions during steady state operation, motor starting and power system transients. The lack of air gap between the surfaces of each terminal lead extension and the earth (terminal box enclosure) that have difference in potential leads to partial discharges. Partial discharges deteriorate the insulation on the terminal leads, leading to failures in the motor. Hence, this requirement ensures that the terminal lead extensions from the stator winding routed internally up to the terminal box are properly insulated and separated between terminal leads and surfaces with different potential.

11.4.4.10

Winding connections, except those completed in the main terminal box, shall be brazed using a silver-based brazing material.

Justification

Historical data confirms that wherever these connections have been crimped, only those connections fail. Brazing or soldering is also deployed as it is proven to provide a connection that is stronger over time. While the results of brazing are superior, the practicalities of brazing that can cause damage to the insulation can be challenging due to the high temperature involved, therefore manufacturers were consulted on how this is addressed (manufacturers were consulted during the development of IOGP S-745). Based on the manufacturers' responses, the requirement is considered feasible and acceptable for standardization.

11.4.4.11

The windings of the motor shall be star connected.

Justification

When the stator winding in STAR configuration is connected to high voltage, the phase current remains the same as the line current, but the phase voltage reduces to Vph = Vline/1.732, which means that the insulation requirement from the phase winding will be less. Though as per 11.4.4.3, the winding coils have uniform insulation levels rated for line-to-line voltage to ensure that the insulation thickness is consistent throughout the stator winding all along its length. Thus, the phase voltage applied on the winding coils with insulation levels rated for line-to-line voltage will further reduce the stress, thereby furthering the life of the insulation system of the winding. The six ends of the stator windings are brought out into the terminal boxes (three ends to the main terminal box and three ends to the neutral terminal box). For differential protection, when required, either full differential or self-balancing scheme is arranged with the six ends of the stator windings as applicable. This requirement, along with the data sheet element for neutral connection, ensures that the terminal boxes are adequately sized for all six ends of the stator windings.

11.4.5 Rotor

11.4.5.1

The shaft of the rotor shall be manufactured from one of the following:

– hot-rolled and normalized steel;

– a single billet of heat-treated forged steel.

Justification

This requirement ensures that the torsional strength of the rotor shaft is not compromised and is uniform throughout the shaft length. Shafts made of hot-rolled round steel are most common in small and medium-sized motors. Hot rolling is a mill process which involves rolling the carbon structural steel at a high temperature (typically at a temperature over 927 °C) which is above the recrystallization temperature of the steel. When the steel material is above the recrystallization temperature, it can be shaped and formed easily, and be made in much larger sizes. The block diameter is selected in accordance with the maximum diameter of the shaft anywhere along its length plus the machining allowance. Therefore, the amount of cutting is relatively large. Hot rolling improves the following:

– *toughness and strength;*
– *ductility;*
– *resistance to vibration and shock;*
– *formability;*
– *weldability.*

Forged shafts are preferred for larger shaft diameters. The forged steel has high mechanical strength and the general shape of the stepped shaft can save raw materials and cutting time, but forged shafts are more expensive than hot-rolled shafts. The advantages of forging include the following.

– *It is generally tougher than alternative manufacturing techniques.*
– *The nature of forging excludes the occurrence of porosity, shrinkage, cavities and cold pour issues.*
– *The tight grain structure of forgings makes it mechanically strong. There is less need for expensive alloys to attain high-strength components.*
– *The tight grain structure offers great wear resistance without the need to make products "super hard".*

11.4.5.2

Where shaft keys are provided, rotors shall be balanced with a half-key fitted in the shaft keyway in accordance with IEC 60034-14 and ISO 21940-32.

Justification

Rotor shaft construction and balancing requirements ensure consistency across operators and manufacturers with a minimum specification. The rotor shaft is balanced in accordance with IEC 60034-14:2018, Clause 7 with the keyway in accordance with ISO 21940-32. This requirement is generally the default for manufacturers but is currently not covered in IEC 60034-1.

11.4.5.3

Rotors shall be balanced to restrict the residual unbalance below the permissible limit determined by the specified balance quality grade.

Justification

As part of the rotor balancing, ensuring minimum residual unbalance is a good start to achieve low vibration values in a completely assembled machine. Setting the limits for residual unbalance based on balance grade G 2,5 is the typical industry practice for large motor unbalance. This requirement allows the purchaser to procure machines with lower residual unbalance magnitudes by pointing to a PDS element that specifies the required balancing grade to determine the permissible limits for residual unbalance.

11.4.5.4

Rotors with rigid shaft characteristics shall be balanced in accordance with ISO 21940-11.

Justification

The balance grade is defined to ensure consistency. ISO 21940-11:2016, Table 1 defines the actual requirement and level of accuracy required. The applicable category is "Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min". ISO 21940-11 also describes the balancing process. The maximum shaft vibration and run out limits are specified in the PDS.

11.4.5.5

For converter duty motors with rigid shaft characteristics, the maximum vibration magnitude limits shall be applicable throughout the defined speed range.

Justification

The balance grade is defined to ensure consistency. ISO 21940-11:2016, Table 1 defines the balancing quality grades for typical machinery categories. The applicable category is "Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min". ISO 21940-11 also describes the balancing process. This requirement supplements 11.4.5.4 by stating that the maximum vibration magnitude is applicable not only for the maximum rated speed but for the entire defined speed range for a converter duty motor. The maximum shaft vibration and run-out limits are specified in the PDS.

11.4.5.6

Rotors with flexible shaft characteristics shall be balanced at rated speed in accordance with ISO 21940-12.

Justification

Balancing rigid shafts is performed at a speed that is not considered critical, however this is not the case for a flexible shaft machine. This type of rotor is balanced at a low speed where the rotor does not flex. Correction for unbalance is made, then the speed is gradually increased and the unbalance is corrected in stages until the rated/operating speed of the rotor is reached. This requirement ensures that the rotor does not flex in the entire range up to the rated speed. The maximum shaft vibration and run-out limits are specified in the PDS.

11.4.5.7

For converter duty motors with flexible shaft characteristics, the maximum vibration magnitude limits shall be applicable throughout the defined speed range.

Justification

When balancing rigid shafts, it is a given that balancing is performed at a speed that is not considered critical, however, this is not the case for a flexible shaft machine. This type of rotor is balanced at a low speed where the rotor does not flex. Correction for unbalance is made, then the speed is gradually increased and the unbalance is corrected in stages until the rated/operating speed of the rotor is reached. This requirement ensures that the rotor does not flex in the entire range up to the rated speed. This requirement supplements 11.4.5.6 by stating that the maximum vibration magnitude is applicable not only for the maximum rated speed but for the entire defined speed range for a converter duty motor. The maximum shaft vibration and run-out limits are specified in the PDS.

11.4.5.8

Rotor shaft ends shall be provided with an ISO metric threaded hole to facilitate coupling and rolling element bearing removal.

Justification

This requirement for a threaded hole ensures that maintenance/breakdown activities are facilitated in a timely manner with minimal downtime.

11.4.5.9

For motors with sleeve bearings, the rotor shall be permanently marked to be visible in operation and standstill position with the magnetic centre and limits of permissible shaft axial movement.

Justification

This requirement facilitates the monitoring of bearing performance and condition when the motor is in use. It provides the user with the ability to identify a bearing malfunction in the early stages and reduces the chances of bearing failure becoming catastrophic.

11.4.5.10

Shaft extensions shall be in accordance with IEC 60072-2.

Justification

IEC 60072-2 ensures that dimensions are uniform across manufacturers. This requirement ensures that the motor is replaceable and interchangeable.

11.4.5.11

The proximity probe sensing areas on the rotor shaft shall be concentric with the bearing journal, free from stencil and scribe marks and from surface discontinuity.

Justification

Contactless probes enable maintenance-free long-term measurements in industrial environments. The application of these probes requires the measurement surfaces on the shaft to be specially machined. Ideally, these surfaces should be round, cylindrical and concentric with the rotational axis. The measurement surfaces are usually located close to each bearing journal. Imperfections in the surfaces appear in the probe response and result in measurement error. API Standard 541:2014, 4.4.5.1.7 specifies the preparation of the rotor sensing area to prevent measurement errors/issues. Activities such as metallizing, sleeving and plating on the measurement area introduces variation in metal properties/characteristics and result in measurement errors/issues during rotor surface sensing. IEC 60034-1 does not specify requirements related to preparation of rotor sensing area. Hence, compliance in accordance with API standards ensures standardization and ensure the elimination of measurement errors/issues due to surface anomalies.

11.4.5.12

The proximity probe sensing areas on the rotor shaft shall not be metallized, sleeved or plated.

Justification

Contactless probes enable maintenance-free long-term measurements in industrial environments. The application of these probes requires the measurement surfaces on the shaft to be specially machined. Ideally, these surfaces should be round, cylindrical and concentric with the rotational axis. The measurement surfaces are usually located close to each bearing journal. Imperfections in the surfaces appear in the probe response and result in measurement error. API Standard 541:2014, 4.4.5.1.7 specifies the preparation of the rotor sensing area to prevent measurement errors/issues. Activities such as metallizing, sleeving and plating on the measurement area introduces variation in metal properties/characteristics and result in measurement errors/issues during rotor surface sensing. IEC 60034-1 does not specify requirements related to preparation of rotor sensing area. Hence, compliance in accordance with API standards ensures standardization and ensure the elimination of measurement errors/issues due to surface anomalies.

11.4.5.13

The proximity probe sensing areas on the rotor shaft shall achieve a surface finish of maximum 0,8 µm arithmetic average roughness.

Justification

Contactless probes enable maintenance-free long-term measurements in industrial environments. The application of these probes requires the measurement surfaces on the shaft to be specially machined. Ideally, these surfaces should be round, cylindrical and concentric with the rotational axis. The measurement surfaces are usually located close to each bearing journal. Imperfections in the surfaces appear in the probe response and result in measurement error. API Standard 541:2014, 4.4.5.1.7 specifies the preparation of the rotor sensing area to prevent measurement errors/issues. Activities such as metallizing, sleeving and plating on the measurement area introduces variation in metal properties/characteristics and result in measurement errors/issues during rotor surface sensing. IEC 60034-1 does not specify requirements related to preparation of rotor sensing area. Hence, compliance in accordance with API standards ensures standardization and ensure the elimination of measurement errors/issues due to surface anomalies.

11.4.5.14

The electrical and mechanical runout of the rotor shaft supported on v-blocks shall be measured at least every 10° of rotation on each probe location with the rotor rotated through the full 360°.

Justification

Suppliers often demonstrate the compliance but do not provide elaborate measurements and the associated report of the test. The test results form the baseline data for any future investigation related to vibration issues. Hence, the electrical and mechanical runout readings of the rotor shaft measured at least every 10° of rotation with the rotor rotated through the full 360° when supported on v-blocks should be recorded. Similarly, the electrical and mechanical runout readings of the rotor shaft in the assembled machine should be measured at least every 10° of rotation with the rotor rotated through the full 360° at slow roll speed (200 rpm to 300 rpm). These test results of electrical and mechanical runout for the full 360° at each probe location have to be part of the documentation in the manufacturer's record book (MRB).

11.4.5.15

The electrical and mechanical runout of the rotor shaft in the assembled machine shall be measured at least every 10° of rotation on each probe location with the rotor rotated through the full 360° at slow roll speed (200 rpm to 300 rpm).

Justification

Suppliers often demonstrate the compliance but do not provide elaborate measurements and the associated report of the test. The test results form the baseline data for any future investigation related to vibration issues. Hence, the electrical and mechanical runout readings of the rotor shaft measured at least every 10° of rotation with the rotor rotated through the full 360° when supported on v-blocks should be recorded. Similarly, the electrical and mechanical runout readings of the rotor shaft in the assembled machine should be measured at least every 10° of rotation with the rotor rotated through the full 360°at slow roll speed (200 rpm to 300 rpm). These test results of electrical and mechanical runout for the full 360° at each probe location have to be part of the documentation in the MRB.

11.4.5.16

Unless approved by the purchaser, components on the rotor assembly shall not be repaired by plating, plasma spray, metal spray, impregnation, or welding.

Justification

Operators have experienced that minor shaft damages during manufacturing (assembly/testing) gets repaired/rectified using processes that do not address heat stress relieving, which cause defects later. Suppliers adopt non-standard material and processes for rotor repairs when not explicitly addressed in the specification. The absence of this requirement has led to dispute between purchasers and suppliers. This requirement eliminates the ambiguity and a potential dispute.

11.4.5.17

Rotor balance corrections shall be in accordance with API Standard 541:2021, 4.4.6.3.2.

Justification

Operators have experienced suppliers adopting non-standard material and processes for rotor balance corrections since it is not explicitly addressed in the specification. API Standard 541:2021, 4.4.6.3.2 adequately addresses the rotor balance correction requirements, hence this requirement eliminates the ambiguity and a possible dispute.

11.4.5.18

Current carrying components on the rotor shall be copper, or copper alloy.

Justification

Theoretically, cast aluminium used for rotor construction is acceptable irrespective of the rotor size if the rotor casting is free from porosity. Experience shows that cast aluminium rotor for motors rated up to about 750 kW are reliable. Above this value of power rating, rotors are large and the molten aluminium loose heat too fast during the casting process, not allowing the bubbles to escape in time, thus causing in casting porosity. These pores (casting defects) cause unbalanced rotor currents, uneven heating, uneven magnetic fields and higher vibration in the rotor. Fabricated aluminium for rotor bars for motors rated up to 750 kW are acceptable since the bending stresses on the rotor bars between the laminations and end rings are not excessive. However, copper or copper alloy is a better alternative as current carrying components on the rotor and eliminate the drawbacks of aluminium castings. This requirement standardizes the rotor cage material while the purchaser can still approve cast aluminium rotor construction, if the supplier raises deviation.

11.4.6 Terminals

Terminal bushings and post insulators shall be made of cycloaliphatic epoxy resin material.

Justification

Cycloaliphatic epoxy resin is a low viscosity, low molecular weight epoxy resin designed for use in high-voltage outdoor electrical applications because it achieves crack-free components with excellent mechanical and electrical properties with high uniformity. Cycloaliphatic epoxy resins are alternatives to standard bisphenol epoxies because they have superior resistance to moisture and ultraviolet (UV), better colour and gloss stability, excellent electrical properties, high heat deflection temperature and high compression strength. High compression strength and other qualities of cycloaliphatic epoxy resin make the insulators from these epoxy resins reliable for many years of service. This requirement aligns with API Standard 541:2014, 5.1.1.

11.4.7 Terminal boxes

11.4.7.1

The main terminal box shall be made of fabricated steel with a thickness greater than or equal to 3 mm.

Justification

This requirement is not covered in IEC 60034-1 and ensures that terminal boxes are made of a material and of a thickness that aligns with the operating life of the machine body. The specified thickness is consistent with the manufacturer's standard offerings and aligns with API Standard 541:2014, 4.4.1.1.

11.4.7.2

The main terminal box shall withstand for a duration of 0,1 s the pressure buildup resulting from the specified three-phase peak fault current at motor terminals.

Justification

This requirement ensures that the specified value of the peak fault current that the motor terminals see in case of a three-phase fault does not cause damage to the main terminal box. The motor terminal box is designed to withstand the pressure buildup for a duration of 0,1 s and survive the three-phase peak fault. This requirement aligns with API Standard 541:2014, 5.1.2.

11.4.7.3

Main, neutral and auxiliary terminal boxes shall have terminal markings and the direction of rotation in accordance with IEC 60034-8.

Justification

IEC 60034-8 provides a letter designation to the terminals for the connection diagram of the motor windings. This requirement provides a standard method for terminal markings and the direction of rotation that is commonly understood by suppliers and users.

11.4.7.4

Where provided, threaded cable gland entries shall have a metric thread in accordance with IEC 60423:2007, Table 1.

Justification

This requirement ensures that terminal box gland entries are consistent with no variation in thread size/pitch across manufacturers.

11.4.7.5

Cable entries shall be fitted with blanking devices to retain the ingress protection rating of the motor during transportation and storage.

Justification

This requirement ensures that the intended ingress protection rating is maintained during transportation and storage and until the installation of cables is completed.

11.4.7.6

Where single-core power cables are specified, the gland plate and multi-cable transit frame shall be made of non-magnetic material.

Justification

Where single-core cables are used for each phase, the magnetic flux does not cancel out as it does in case of a three-core cable. This causes the individual cable magnetic flux to produce eddy current circulation in the metallic plate, causing overheating of the gland plate. Hence, the gland plate or multi-cable transit frame is made of non-magnetic material to prevent eddy current and heating. Though this phenomenon is widely recognized, it is not specified in IEC 60034-1, hence this requirement.

11.4.7.7

Where provided, the neutral terminal box shall be located on the opposite side of the main terminal box.

Justification

Mounting the neutral terminal box (which would typically be required for current transformers with full differential protection scheme) opposite the line conductor terminal is standard practice among manufacturers. Moreover, it is not practical to locate both large terminal boxes on one side and locating one on either side achieves the best balance in order to provide convenient access for installation, testing and maintenance.

11.4.7.8

For non-Ex db main terminal boxes, a corrosion-resistant pressure-relief diaphragm shall be incorporated in the terminal box.

Justification

Safety and integrity of high-voltage terminal boxes during internal faults are ensured by deliberately incorporating a weak spot within the terminal box. In normal operation, the cable box is adequately sealed and maintains the integrity and enclosure protection level. In the event of an internal fault, a relatively modest rise in pressure within the box ruptures the pressure-relief diaphragm and relieves the energy, preventing damage to the terminal box. The location of the pressure-relief diaphragm is also important as during the rupture of the diaphragm, the pressure is released away from where any personnel could be present. Also, the corrosion resistance property ensures that environmental effects do not affect the integrity of the diaphragm.

11.4.7.9

The discharge of the pressure-relief diaphragm shall be located on the back panel of the terminal box and directed towards the motor frame.

Justification

Safety and integrity of high-voltage terminal boxes during internal faults are ensured by deliberately incorporating a weak spot within the terminal box. In normal operation, the cable box is adequately sealed and maintains the integrity and enclosure protection level. In the event of an internal fault, a relatively modest rise in pressure within the box ruptures the pressure-relief diaphragm and relieves the energy preventing damage to the terminal box. The location of the pressure-relief diaphragm is also important as during the rupture of the diaphragm, the pressure is released away from where any personnel could be present.

11.4.7.10

The bottom of the terminal box shall be higher than the mounting surface of the motor.

Justification

This requirement ensures that the motor mounting base is the lowest point and that terminal boxes can remain installed on the motor housing even during transport and storage. This requirement ensures that the motor can be installed on the base frame without any additional structural assembly required to elevate the lowest point of the motor up to or above the base frame level. When stated upfront, this requirement helps the manufacturer to choose the tilt and orientation of the terminal box at the initial stage.

11.4.7.11

Motor auxiliaries and instruments shall be wired to separate auxiliary terminal boxes mounted on the side of the motor.

Justification

This requirement ensures that the number of auxiliary terminal boxes is in accordance with the segregation of signals and that the location of these boxes on the motor housing and routing of wiring are determined uniformly by all manufacturers. This requirement rules out the possibility of combining manufacturers auxiliary terminal boxes.

11.4.8 Fans

11.4.8.1

Separable fans shall be permanently indexed angularly and axially.

Justification

Rotors need to be removed for many maintenance operations. If fan impellers are mounted external to the rotor end shields, the fans are removed as part of the rotor removal process. It is important to maintain the same relative position between the rotor and the fan when the fan is reinstalled such that the rotor balance is maintained. Keying or screwing to the rotor shaft is a simple and accurate method of ensuring this alignment.

11.4.8.2

Slip-fitted fans shall not be secured to the shaft only by means of set/grub screws.

Justification

Rotors need to be removed for many maintenance operations. If fan impellers are mounted external to the rotor end shields, the fans are removed as part of the rotor removal process. It is important to maintain the same relative position between the rotor and the fan when the fan is reinstalled such that the rotor balance is maintained. Keying or screwing to the rotor shaft is a simple and accurate method of ensuring this alignment. There are multiple ways to secure slip-fitted fans on the shaft but use of only set/grub screws is not adequate as these screws tend to loosen over a period of time. In addition to fixing by means of set/grub screws, one more method of securing the fans prevents loosening of the fans on the shaft.

11.4.8.3

Motors with unidirectional fans shall have a permanently affixed label with an arrow indicating the direction of rotation.

Justification

Where a unidirectional fan is provided, the engraved arrow helps the installer of the fan to confirm the orientation for which the fan should be installed, ensuring it operates as per the design. The arrow is also a check for the direction of rotation of the driver to ensure the phase sequence of the power cables.

11.4.8.4

Where a corrosivity category greater than C3 has been specified, fan impellers external to the stator end shields shall not be made of aluminium.

Justification

With the exception of some internal fans, this requirement prohibits aluminium fan impellers in environments with a corrosivity factor greater than C3 due to the increased corrosion that aluminium typically incurs compared to steel or glass reinforced plastic (GRP). However, some internal fans made of aluminium are not prohibited due to protection from external environmental factors.

11.4.8.5

Fan covers shall be made of ferrous metal.

Justification

In general, manufacturer documentation shows that for high-voltage motors of smaller frame sizes, cast iron frames are standard with a metal fan cover. For Ex motors, cast-iron framed motors can have either a steel or a hot-dip galvanized steel fan cover. This requirement rationalizes the variants available and excludes the use of aluminium and GRP which both have implications with corrosion and withstanding impacts which are predominant issues in the industry.

11.4.9 Bearing and lubrication

11.4.9.1 Bearing insulation

11.4.9.1.1

The bearing housing shall bear a prominent label to indicate the use of insulated bearings.

Justification

The caution label on the bearing housing states that no action causes the bearing insulation to be bridged by any conductive connection. This requirement also cautions for appropriate replacement spares and compliance to procedures as recommended by the manufacturer to maintain the integrity of bearing insulation.

11.4.9.1.2

When drive end and non-drive bearings are insulated, a shaft grounding system shall be provided at the drive end of the rotor shaft.

Justification

When insulating both bearings, it is 100 % effective in stopping the circulating current. However, the voltage on the shaft of the machine then rises to a maximum and seeks a path to the ground through the attached equipment. This situation can also put the coupled equipment bearings a risk. Therefore, a means of providing a path to the ground is installed to discharge these shaft voltages. The shaft grounding provides a means of discharging these shaft voltages.

11.4.9.2 Sleeve bearings

11.4.9.2.1

Sleeve bearings shall be spherical seated and self-aligning.

Justification

On spherical seated self-aligning sleeve bearings, the outer rings get press fit into housings. This requirement allows the fracture to remain closed and prevents the rotation of the outer ring under heavy rotational or oscillating loads. Inner rings may have interference or clearance fits on shafts depending on the application. To facilitate the mounting of bearings of this design, the ends of pins or shafts and the edges of housing bores have a lead chamfer of 10° to 20°. These bearings can be more easily pressed into position and there is little risk of damage to mating surfaces caused by skewing of the bearing. This ultimately facilitates a more efficient bearing replacement, with less opportunity to damage the bearing housing faces, which minimizes additional motor downtime.

11.4.9.2.2

Replacement of sleeve bearing liners, pads and shells shall be possible without disassembly of the lower half of the end bells, plates and ductwork or without disassembly of the coupling on the motor.

Justification

This requirement enables rectification work to be performed on sleeve bearings with minimal disruption and outage time.

11.4.9.2.3

The motor shall start and run without the need for jacking oil to the sleeve bearings.

Justification

When the motor shaft is rotating very slowly or during start-up phase and shut-down phase, the normal lubricating oil supply cannot ensure an adequate hydrodynamic oil wedge to prevent bearing damage/breakdown. Additional pumps provide the necessary high pressure jacking oil to lift the motor shaft within the sleeve bearings prior to starting the rotation of the shaft and prevent bearing damage. Sleeve bearings can be designed such that they do not require jacking oil, but again it also depends on the weight (mass) of the shaft and the space available for journals and bearings.

11.4.9.2.4

Self-lubricated sleeve bearings shall be provided with an oil level indicator.

Justification

This requirement provides lubrication level monitoring to ensure that maintenance activities can identify a low oil level without performing intrusive maintenance. This allows trends to be easily monitored if increased oil usage or any leakage occurs.

11.4.9.2.5

Sleeve bearings with a ring lubricating system shall permit the visual inspection of oil ring operation while the motor is running.

Justification

Visual inspection while the motor is running provides the user with a non-intrusive means of ensuring that the lubrication system is operating properly on a regular basis. Some manufacturers recommend checking oil ring operation daily.

11.4.9.2.6

For flooded lubrication systems with a lube oil re-circulation circuit of sleeve bearings, a flow indicator shall be provided in the lube oil return lines.

Justification

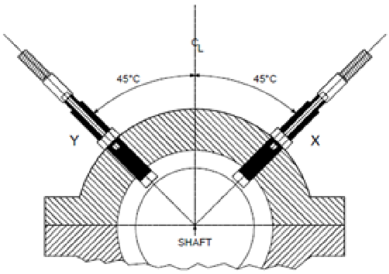
This requirement provides lubrication oil flow monitoring to ensure that maintenance activities can identify low oil flow without performing intrusive maintenance.

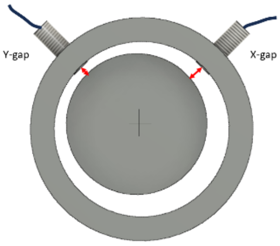
11.4.9.2.7

Machines shall have provision for two non-contacting vibration measurement proximity probes per sleeve bearing and one phase reference transducer in accordance with API Standard 670.

Justification

This requirement ensures that the machine is provided with a means for vibration measurement. API Standard 670 provides further definition on proximity sensor specification. Proximity probes are sensors that detect objects without coming into physical contact, thereby measuring the shaft displacement relative to the sleeve bearing housing. Typically, two proximity probes identified as X and Y are mounted per sleeve bearing at a 45-degree angle from vertical, thus being at a 90-degree angle apart from one another, as shown in Justification Figure c and Justification Figure d. The relative motion between the shaft and the probes generates varying eddy current flow that gives a proportional corresponding change in both the amplitude and phase of the signal. This signal is then interpreted as shaft displacement and runout. The phase reference transducer provides a relative reference point for the vibration readings from the proximity probes and helps with monitoring/diagnostics information such as filtered vibration amplitude, phase lag and speed.





Justification Figure c *Justification Figure d*

11.4.9.2.8

Oil and bearing metal temperatures of sleeve bearings shall be in accordance with API Standard 541:2014, 4.4.7.1.14.

Justification

The bearing over-temperature is the most common cause of premature bearing failure and stating a maximum temperature provides alignment for industry requirements.

11.4.9.2.9

If the sleeve bearing flooded lubrication system fails or is switched off, the motor shall rundown safely.

Justification

Oil reservoirs or rundown tanks are simple vessels used for the storage of oil above a certain height from the shaft centre line of the rotary equipment (e.g. motor, generator, pump, compressor). Bearings are critical parts of the rotating machine with a high level of sensitivity and even a small damage can ruin the bearing rapidly. The most probable cause of bearing damage is reduced lubrication or loss of lubrication. This situation is likely to happen in case of a power interruption when the method of flood lubrication or pressure lubrication is used. Another cause could be someone switching off the pump by mistake. To counter this situation, the oil reservoir or rundown tank supplies the lubrication oil to the bearings at the required flow rate, pressures until the equipment coasts down (runs down) and comes to a standstill. This arrangement keeps the bearing adequately lubricated and protects it from damage. Typically, the status of the oil level in the reservoir is used as a start permissive interlock in the equipment starting logic.

11.4.9.3 Tilting pad bearings

11.4.9.3.1

The motor shall start and run without the need for jacking oil to the tilting pad bearings.

Justification

When the motor shaft is rotating very slowly or during start-up and shut-down phases, the normal lubricating oil supply cannot ensure an adequate hydrodynamic oil wedge to prevent bearing damage/breakdown. Additional pumps provide the necessary high pressure jacking oil to lift the motor shaft within the sleeve bearings prior to starting the rotation of the shaft and prevent bearing damage. Sleeve bearings can be designed such that they do not require jacking oil, but it also depends on the weight (mass) of the shaft and the space available for journals and bearings.

11.4.9.3.2

Self-lubricated tilting pad bearings shall be provided with an oil level indicator.

Justification

This requirement provides lubrication level monitoring to ensure that maintenance activities can identify a low oil level without performing intrusive maintenance. This allows trends to be easily monitored if increased oil usage or any leakage occurs.

11.4.9.3.3

For flooded lubrication systems with a lube oil re-circulation circuit of tilting pad bearings, a flow indicator shall be provided in the lube oil return lines.

Justification

This requirement provides lubrication oil flow monitoring to ensure that maintenance activities can identify low oil flow without performing intrusive maintenance.

11.4.9.3.4

Oil and bearing metal temperatures of tilting pad bearings shall be in accordance with API Standard 541:2014, 4.4.7.1.14.

Justification

The bearing over-temperature is the most common cause of premature bearing failure and stating a maximum temperature provides alignment for industry requirements.

11.4.9.3.5

If the tilting pad bearing flooded lubrication system fails or is switched off, the motor shall rundown safely.

Justification

Oil reservoirs or rundown tanks are simple vessels used for the storage of oil above a certain height from the shaft centre line of the rotary equipment (e.g. motor, generator, pump, compressor). Bearings are critical parts of the rotating machine with a high level of sensitivity and even a small damage can ruin the bearing rapidly. The most probable cause of bearing damage is reduced lubrication or loss of lubrication. This situation is likely to happen in case of a power interruption when the method of flood lubrication or pressure lubrication is used. Another cause could be someone switching off the pump by mistake. To counter this situation, the oil reservoir or rundown tank supplies the lubrication oil to the bearings at the required flow rate, pressures until the equipment coasts down (runs down) and comes to a standstill. This arrangement keeps the bearing adequately lubricated and protects it from damage. Typically, the status of the oil level in the reservoir is used as a start permissive interlock in the equipment starting logic.

11.4.9.4 Rolling element bearings

11.4.9.4.1

Rolling element bearings shall be regreasable with a minimum lubrication interval in accordance with Table 28.

Justification

This requirement ensures that excessive maintenance is not incurred as a result of specifying rolling element bearings. This gives the user consistency for planned maintenance frequency for high-voltage motors. The values stated in Table 28 are aligned with manufacturers' standard offerings.

Add new Table 28

Table 28 – Lubrication intervals of grease-lubricated rolling element bearings

Motor mounting type	Lubrication interval h
Horizontal	≥ 4 000
Vertical	≥ 2 000

Justification

This table ensures that excessive maintenance is not incurred as a result of specifying rolling element bearings. This gives the purchaser consistency for planned maintenance frequency for high-voltage motors. The values stated in this table are aligned with manufacturers' standard offerings.

11.4.9.4.2

Rolling element bearings clearance shall be C3 type in accordance with ISO 5753-1:2009, Table 1, Group 3.

Justification

C3 refers to normal clearance as commonly used to prevent too little internal bearing clearance in operation. This reduces variations and is considered the default choice for high-voltage motors up to circa frame size 450 in the oil and gas industry. Most manufacturers offer this as standard or as an existing option.

11.4.9.4.3

The minimum L_{10h} bearing design lifetime in accordance with ISO 281 shall be in accordance with Table 29.

Justification

This requirement ensures that operators have stipulated a minimum requirement for the performance of bearings on vertically-mounted motors as well as horizontally-mounted motors. Bearing life is extended from average of 40 000 h (existing IEC industry standard) to 50 000 h for horizontally-mounted motors. This requirement was reviewed with various manufacturers and confirmation was obtained that they could achieve this requirement without additional cost. The value of 40 000 h for vertically-mounted motors has been confirmed as a standard offering from manufacturers, however it is recognized that this leads to the installation of an angular contact bearing and to the purchaser specifying the magnitude of axial force of the load to the manufacturer in the PDS.

Add new Table 29

Table 29 – Minimum L_{10h} bearing design lifetime

Motor mounting type	Minimum L_{10h} bearing design lifetime h
Horizontal	50 000
Vertical	40 000

Justification

This requirement ensures that operators have stipulated a minimum requirement for the performance of bearings on vertically-mounted as well as horizontally-mounted motors. Bearing life is extended from average of 40 000 h (existing IEC industry standard) to 50 000 h for horizontally-mounted motors. This requirement was reviewed with various manufacturers and it was confirmed that they could achieve this requirement without additional cost. The value of 40 000 h for vertically-mounted motors has been confirmed as a standard offering from manufacturers, however it is recognized that this leads to the installation of an angular contact bearing and to the purchaser specifying the magnitude of axial force of the load to the manufacturer in the PDS.

11.4.9.4.4

Motors with rolling element bearings shall have provision for specified vibration measurement sensors per bearing.

Justification

This requirement ensures that the provision is available for the specified sensor type.

11.4.9.4.5

For motors with no vibration sensor provision, the bearing housings of the motor shall have a flat surface with two positions X and Y clearly marked for measurement using a portable vibration sensor.

Justification

A portable vibration sensor is used to measure casing vibration on the motor as a complete unit. In many cases, these sensors to be provided are specified in the PDS and where this is not the case, it is highly likely that throughout the design life of the motor, vibration measurement is done by means of a portable vibration sensor, hence this requirement.

11.4.9.4.6

Lubrication ports of rolling element bearings shall be accessible while the motor is running.

Justification

This requirement ensures that it is possible to re-lubricate motor bearings while the motor is running, thereby improving the motor availability while maintaining reliability.

11.4.9.4.7

Rolling element bearings shall use grease that contains mineral-based oil and lithium complex thickener.

Justification

This requirement provides consistency for grease specification for rolling element bearings. Lithium-based grease exhibits good stability and provides better performance for high temperature and moisture resistance. The use of such grease prevents premature wear of the rolling element bearings, especially in typical harsh environments of the oil and gas industry.

11.4.9.4.8

Grease-lubricated rolling element bearing assembly shall be provided with a labyrinth seal and a grease-relief valve.

Justification

While the re-lubrication is performed, the grease follows a guided path through the bearing gaps and pushes out the old, used grease through the grease-relief valve or drain plug. The labyrinth seal helps prevent the pressurized grease to find its way between the shaft and the inner bearing cap into the inside of the motor. It also prevents loss of grease and ingress of dust or moisture.

11.4.9.4.9

Selection of rolling element bearings for horizontal motors shall be in accordance with API Standard 541:2014, 4.4.7.1.3.

Justification

API Standard 541 determines the selection of rolling element bearing based on the dN factor method. The dN factor is the product of bearing size in millimetres and speed in revolutions per minute. The other parameter influencing the selection is L10 rating life of bearings based on loading at the rated speed.

11.4.9.4.10

Selection of rolling element bearings for vertical motors shall be in accordance with API Standard 541:2014, 4.4.7.1.4 and 4.4.7.1.5.

Justification

API Standard 541 determines the selection of rolling element bearing based on the dN factor method. The dN factor is the product of bearing size in millimetres and speed in revolutions per minute. The other parameter influencing the selection is L10 rating life of bearings based on maximum up and down thrust during starting, stopping or operation at the rated load.

11.4.9.4.11

Rolling element bearings shall have a metallic cage.

Justification

Bearing cages are provided to separate the rolling elements to reduce the frictional heat, keep the rolling elements evenly spaced to optimize load distribution, guide the rolling elements in the unloaded zone of the bearing and retain the rolling elements of separable bearings when one bearing ring is removed. Cages are made of metal, plastic or composite material. Though non-metallic cage material is gaining popularity due to their light weight, very low coefficient of friction, higher strength to weight ratio and insulating properties, they do not have adequate life expectancy. Metallic cages offer better performance under high levels of vibrations, exhibits good thermal conductivity and increased life expectancy in arduous operating conditions which is desirable in industrial environment.

11.4.9.4.12

Rolling element bearings shall be a metric size and conform to ISO 15 and ISO 492.

Justification

These standards specify the dimensional and geometrical characteristics, limit deviations from nominal sizes, and tolerance values of bearings ensuring that standard bearings are used. This supports service/maintenance and inventory management.

11.4.10 Lateral analysis

When specified, lateral analysis shall be carried out for test floor and final site conditions in accordance with API Standard 541:2014, 4.4.6.2.1.

Justification

Lateral vibration of a shaft rotor is caused by instability, rotor mass, unbalance or other forces acting on the rotor. Lateral analysis simulates the rotating system, calculates the critical speeds, predicts vibration amplitudes and provides data that may result in additional measures applied by the manufacturer to reduce vibration risks. The analysis is also impacted by the foundation stiffness and damping. When the foundation data is significantly different between the test floor and final site conditions, additional analysis is done. The foundation data for the factory acceptance test is the manufacturer's test floor conditions and the foundation data for the site acceptance test is the final site conditions. This requirement specifies that lateral vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 541:2014, 4.4.6.2.1.

11.4.11 Torsional analysis

When specified, torsional analysis shall be performed in accordance with API Standard 541:2014, 4.4.6.2.2.

Justification

This requirement defines how torsional vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 541:2014, 4.4.6.2.2.

11.4.12 Monitoring and protection devices

11.4.12.1 General

11.4.12.1.1

External connections between motor-mounted devices and respective terminal boxes shall be routed in steel conduits clamped on the motor frame.

Justification

These mounted devices are small instrumentation devices (such as sensors, probes and transducers) that have flexible and thin connecting cable leads. This requirement ensures that these devices are grouped in accordance with signal category and wired to the respective auxiliary terminal boxes located on the motor frame. Since these devices are located all over the motor surface depending on their application, the connecting cable leads are routed on the motor surface up to the auxiliary terminal boxes safely. The safest way to protect the cables is to route them in a steel conduit that is fixed to the motor frame. Without this requirement, the manufacturer could adopt different means of routing that can be inconsistent and sometimes less safe than desired.

11.4.12.1.2

Each wire shall be connected to an individual terminal in the respective terminal box.

Justification

This requirement ensures that each wire is terminated individually in the terminal box, which ensures that the terminal boxes are adequately sized and provided with the required number of terminations. This ensures that all spare signal inputs are also wired up and connected to the respective systems.

11.4.12.1.3

Three-wire Pt-100 platinum resistance temperature sensors in accordance with IEC 60751 shall be used for temperature detection.

Justification

This requirement standardizes the use of three-wire Pt-100 sensors for temperature measurement. Though two-wire can also work, three-wire is better as the addition of a third wire, connected to one side of the measuring element, helps to compensate for lead resistance. To compensate for lead wire resistance, three-wire RTDs have a third wire that provides a measurement of the resistance of the lead wire and subtracts this resistance from the value read.

11.4.12.2 Winding temperature sensors

Two winding temperature sensors per phase shall be installed to detect the highest temperatures of the stator winding.

Justification

The intent of providing the temperature sensors is to capture the value of the highest temperature attained in any part of the motor. The prospective location is underneath the conductors at the bottom portion of the slot or on the conductors in the end winding portion. The other locations could be the core pack laminations or the pressure plates but the conductors at the bottom portion of the slot or on the conductors in the end winding portion are the most commonly identified as the hottest part and preferred installed locations for temperature sensors. Thus, each phase winding has two sensors that are placed 120° apart. This provides a fairly uniform temperature measurement value during normal operation.

11.4.12.3 Bearing temperature sensors

Where bearing insulation is provided, the integrity of bearing insulation shall remain uncompromised on the installation of the temperature sensor.

Justification

For the installation of temperature measurement, the temperature sensors are installed in a mounting hole, drilled in the bearing housing which reaches the bearing outer race surface. The sensors are fitted very close to the bearing surface to get the most accurate reading. In this effort, this requirement ensures not to breach the integrity of the bearing insulation which is generally placed over the outer race of the bearing which is then the closest to the temperature sensor tip. The mounting provision is located such that under no circumstances, the installation of the sensor interferes with the bearing insulation but still measures the most accurate temperature present on the bearing surface.

11.4.12.4 Heat exchangers

11.4.12.4.1 Air-cooled heat exchangers

For air-cooled heat exchangers, a three-wire Pt-100 temperature sensor shall be provided to measure the temperature of the cooling air leaving the heat exchanger.

Justification

A temperature monitoring facility alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and extreme motor damage can be prevented or minimized.

11.4.12.4.2 Water-cooled heat exchangers

11.4.12.4.2.1

For water-cooled heat exchangers, three-wire Pt-100 temperature sensors shall be provided to monitor the inlet and outlet air temperatures.

Justification

A temperature monitoring facility alerts the user when the performance of the heat exchanger is outside its normal operating values. By identifying deficiencies in a timely manner, prolonged equipment outages can be prevented and extreme motor damage can be prevented or minimized.

11.4.12.4.2.2

Water-cooled heat exchangers shall be provided with leakage detection.

Justification

A leakage detection facility can ultimately save time and cost by identifying deficiencies in a timely manner and can ultimately prevent prolonged equipment outage.

11.4.12.5 Partial discharge monitoring

11.4.12.5.1

Where stator winding partial discharge sensors are provided, the low voltage lead wires shall be connected to the terminals in a dedicated terminal box mounted on the motor frame.

Justification

This requirement ensures that personnel does not access the main high-voltage terminal box and be exposed to high-voltages to get access to the partial discharge sensor lead wire terminals. This is a safety consideration that is normal practice in the oil and gas industry.

11.4.12.5.2

Where stator winding partial discharge sensors are provided, the line conductor terminal box shall be sized to adhere to the installation requirements of the supplier of the sensors.

Justification

This requirement ensures that the size of the line conductor terminal box is adequate to accommodate the partial discharge sensing device as per the spacing and orientation recommendations of the supplier of the sensors. This requirement ensures that the sensor information is obtained before sizing the terminal box, which is not normal practice in general and later causes non-compliance with installation recommendations of the supplier of the sensors.

11.4.13 Anti-condensation heaters

11.4.13.1

Anti-condensation heaters provided around stator windings or within power terminal boxes shall keep the inside temperature 5 K above the ambient air temperature while the motor is not in operation.

Justification

This requirement measures the performance of the anti-condensation heaters. Without a value for temperature rise, there is no assurance that the heater is adequately specified to perform its duty.

11.4.13.2

Anti-condensation heaters shall be wired to terminals in a separate terminal box mounted on the motor frame.

Justification

A separate terminal box ensures that low-voltage and high-voltage terminations are in separate enclosures. It also ensures that personnel are not exposed to low-voltage live terminals when performing work on the main terminal box.

11.4.13.3

A warning label stating "External voltage source" shall be affixed on the cover of the anti-condensation heater terminal box.

Justification

The warning label warns personnel to isolate the low-voltage supply that is from a different source and/or different location from the main power source to the machine.

11.4.14 Additional requirements for converter duty motors

11.4.14.1

Converter duty motors shall be in accordance with IEC TS 60034-25.

Justification

The scope of this specification includes motors used in power drive systems. This requirement details additional considerations and requirements necessary to operate this arrangement. These additional requirements include temperature monitoring, bearing insulation, certification and testing.

11.4.14.2

The stated continuous motor output ratings for converter duty motors shall be in accordance with IEC 61800-2:2021, 5.3.3.

Justification

The continuous output rating as defined in IEC 61800-2:2021, 5.3.3 is defined in terms of motor shaft parameters as follows:

- *rated torque (M_N) [N·m];*
- *rated speed (N_N) [r/min];*
- *maximum rated speed (N_{NMax}) [r/min];*
- *minimum rated speed (N_{NMin}) [r/min];*
- *minimum speed (N_{Min}) [r/min];*
- *maximum rated safe speed (N_{SNMax}) [r/min];*
- *rated output power (P_{sN}) [kW].*

11.4.14.3

When specified, torsional analysis of converter duty motors shall be in accordance with IEC 61800-2:2021, 5.13.2 and API Standard 541:2014, 4.4.6.2.2.

Justification

This requirement defines how torsional vibration and critical speed analysis is performed as this is not specified in IEC 60034-1. This requirement also aligns with API Standard 541:2014, 4.4.6.2.2 and, for converter duty motors, it aligns with IEC 61800-2:2021, 5.13.2.

11.4.15 Motors intended for use in hazardous area

11.4.15.1 Certification

11.4.15.1.1

Motors and their mounted components shall be certified for the specified protection level in accordance with IEC 60079 (all parts).

Justification

IEC 60079 (all parts) specifies the general requirements for construction, testing and marking of Ex equipment and Ex components for the specified protection level and hazardous area. IEC 60079 (all parts) provides guidelines for equipment grouping and equipment protection levels based on the gas group and temperature classification.

11.4.15.1.2

Motors for use in a hazardous area shall be provided with a certificate issued by a notified body or a certification body.

Justification

This requirement ensures that where it may be possible in accordance with IEC 60079 (all parts) to self-certify the equipment, the certification is issued by a notified or certifying body as per oil and gas industry requirements and standard practice.

NOTE A manufacturer's declaration of conformity alone does not satisfy the requirement of 11.4.15.1.2.

11.4.15.2 Flameproof (type Ex db)

Motors with protection level Ex db shall have terminal boxes with protection level Ex eb.

Justification

This requirement aligns with the manufacturers' standard offering and minimal requirement philosophy. This addresses the ambiguity of Ex db machine terminal box classification which without this could be construed as Ex db in its entirety. Ex eb terminal boxes have the advantage to still comply with Zone 1 requirements, and provide a very cost-effective solution that facilitates easy maintenance, and allows cables with lugs to be easily handled and cable terminals to be easily accessed. A terminal box one size larger is possible with easy access and plenty of space to route and handle cables.

Add to subclause

11.4.15.3

The motor shall have bonding straps across joints within or between the motor components.

Justification

Bonding straps ensure that earth continuity is provided across the complete motor assembly. This is especially critical across joints where gaskets are installed. Bonding straps prevent stray current sparking in the enclosure during start up.

11.4.15.4 Pressurized (type Ex pxb and Ex pzc)

The pressurization unit shall provide the following status information:

- purge cycle in progress;
- purge cycle complete;
- pressurized;
- pressure low / pressure fail.

Justification

This requirement ensures that the essential minimum status information for the control system is provided irrespective of the make and model of the pressurization unit.

12 Tolerances

12.1 General

In NOTE 2, replace "IEC Guide 115:2021" with

IEC Guide 115:2023

Justification

Edition 3.0 (2023) supersedes Edition 2.0 (2021).

Bibliography

Add to start of Bibliography

The following documents are informatively cited in the text of this specification, IEC 60034-1, the PDS (IOGP S-704D) or the IRS (IOGP S-704L).

Add to Bibliography

API Specification Q2, *Specification for Quality Management System Requirements for Service Supply Organizations for the Petroleum and Natural Gas Industries*

API Standard 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*

IEC GUIDE 115:2023, *Application of measurement uncertainty to conformity assessment activities in the electrotechnical sector*

IEC 60034-18-1:2022, *Rotating electrical machines – Part 18-1: Functional evaluation of insulation systems – General guidelines*

IEC 60375, *Conventions concerning electric circuits*

IEC 61082-1, *Preparation of documents used in electrotechnology — Part 1: Rules*

IEC 61355-1, *Classification and designation of documents for plants, systems and equipment – Part 1: Rules and classification tables*

IEC 61892-5, *Mobile and fixed offshore units – Electrical Installations – Part 5: Mobile units*

IEEE 620, *IEEE Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines*

IOGP S-715 *, *Supplementary Specification to NORSOK M-501 Surface Preparation and Protective Coatings*

IOGP S-745, *Supplementary Specification to IEC 60034-1 for High-voltage Synchronous Machines*

ISO 3166-1, *Codes for the representation of names of countries and their subdivisions — Part 1: Country code*

ISO 9001, *Quality management systems — Requirements*

ISO 10005, *Quality management — Guidelines for quality plans*

ISO 10209, *Technical product documentation — Vocabulary — Terms relating to technical drawings, product definition and related documentation*

ISO 13880:1999, *Petroleum and natural gas industries — Content and drafting of a technical specification*

ISO 19901-5, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 5: Weight control during engineering and construction*

ISO/IEC Directives, Part 2, *Principles and rules for the structure and drafting of ISO and IEC documents*

* Cited in IOGP S-704J only.

Delete from Bibliography

IEC 60079 (all parts), *Explosive atmospheres*

IEC GUIDE 115:2021, *Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector*

Registered Office
City Tower
Level 14
40 Basinghall Street
London EC2V 5DE
United Kingdom

T +44 (0)20 3763 9700
reception@iogp.org

Brussels Office
Avenue de Tervuren 188A
B-1150 Brussels
Belgium

T +32 (0)2 790 7762
reception-europe@iogp.org

Houston Office
15377 Memorial Drive
Suite 250
Houston, TX 77079
USA

T +1 (713) 261 0411
reception-americas@iogp.org

www.iogp.org